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Seeing Through the Lens of Social Justice:

A Threshold for Engineering

by

Jens David Kabo

A thesis submitted to the Department of Chemical Engineering

In conformity with the requirements for

the degree of Doctor of Philosophy

Queen's University

Kingston, Ontario, Canada

April, 2010

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Abstract

In recent times the need for educational research dedicated to engineering education has been recognised. This PhD project is a contribution to the development of engineering education scholarship and the growing body of engineering education research. In this project it was recognised that problem solving is a central activity to engineering. However, it was also recognised that the conditions for doing engineering are changing, especially in light of pressing issues of poverty and environmental sustainability that humanity currently faces, and as a consequence, engineering education needs to emphasise *problem definition* to a greater extent. One mechanism for achieving this, which has been adopted by some engineering educators in recent years, is through courses that explicitly relate engineering to social justice. However, creating this relationship requires critical interdisciplinary thinking that is alien to most engineering students. In this dissertation it is suggested that for engineering students, and more generally, engineers, looking at their practice and profession through a social justice lens might be seen as a *threshold* that needs to be crossed. By studying the variation present among students in three different courses at three different North American universities, the intention was to understand how students approach and internalise social justice as a perspective on engineering and/or develop their abilities to think critically. A conceptual model to frame the study was developed by combining elements of threshold concept theory and the educational research methodology, phenomenographic variation theory. All three of the courses studied operated on a similar basic pedagogical model, however, the courses were framed differently, with social justice in the foreground or in the background with the focus on, in one case, ethics and in the other, sustainability. All courses studied appeared to be successful in encouraging engineering students to engage in critical thinking and a similar general trend in the development of students'

conceptions of social justice was observed in each of the three courses. However, it does appear that if one is interested in developing an articulated understanding of social justice, with respect to engineering, that an explicit focus on social justice is preferable.

Acknowledgements

Doing a PhD can be quite a solitary journey as one descends further and further into the questions and context under inquiry, and it is almost impossible to have a conversation about the finer details of one's research with people outside an often small group of people (a fact I actually appreciate as it allows me a mental break). However, I would not have been able to reach this final stage of my PhD project without the support of several people, who I now want to thank.

First of all, I want to thank my supervisor Caroline Baillie, who made this PhD possible and who has been a steady companion on this journey from chaos through territories (some of which I never could have imagined beforehand) and finally now out toward the cosmos. Caroline, I really appreciate all your support, patience, and steady belief in my potential and ability as a researcher, especially at those times when I have been in doubt myself. It has been a pleasure!

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Next, I want to acknowledge the new friends I have made in Canada, who have made me feel at home in Kingston as well as older friends from back home who stay in frequent contact—both groups have been important for my sanity and happiness.

Lastly, I want to thank Geoff Roulet, who by giving me the opportunity to crew on his boat made me realise how much I enjoy sailing and let me develop a new skill set quite different from the one I have acquired through doing this PhD.

Statement of Originality

I hereby certify that all of the work described within this thesis is the original work of the author. Any published (or unpublished) ideas and/or techniques from the work of others are fully acknowledged in accordance with the standard referencing practices.

Jens David Kabo

April, 2010

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Chapter 1

Introduction

MIT's Provost: "We are engineers, we solve problems."

Williams: "Do [engineers] solve problems? The big problems of the world ... are far too big for engineers to solve by themselves."

[MIT's Provost and Williams cited from Williams (2002, pp. 29-30)]

The context of engineering is changing. Increasingly, engineering students will graduate and work in a global context, with and for a diverse group of people, and they will face—together with the rest of humanity—the two major interlinked challenges of poverty and environmental sustainability (Catalano, 2006). In addition, Franklin (1999) argues that:

> As I see it, technology has built the house in which we all live. The house is continually being extended and remodelled. More and more of human life takes place within its walls, so that today there is hardly any human activity that does not occur within this house. All are affected by the design of the house, by the division of its space, by the location of its doors and walls. Compared to people in earlier times, we rarely have a chance to live outside of this house. And the house is still changing; it is still being built as well as being demolished. (p. 1)

Engineering has close ties to technology, and in an increasingly technology-dependent and technology-filled world, the impact of the decisions made by engineers will be amplified, especially in light of the challenges of poverty and environmental sustainability. Catalano (2006) argues that engineers need to work to ameliorate and not exacerbate these challenges. Williams (2002), on the other hand, argues that problems like these cannot be solved by engineering only. The question that needs to be considered is how a balance can be found where engineers can contribute in a positive way towards lessening the world's most pressing issues without being blinded by a belief in the infallibility of engineering. There is a growing awareness of this question within the engineering community, for example, according to the Canadian Engineering Accreditation Board (2009):

> The engineering profession expects of its members' competence in engineering, as well as an *understanding of the effect of engineering on society* [italics added]. Thus, accredited engineering programs must contain not only adequate mathematics, science and engineering, but they must also develop communication skills and *an understanding of the environmental, cultural,* economic *and social impacts of engineering on society and of the concept of sustainable development* [italics added]. (p. 11)

Baillie (2006) acknowledges this development, but argues that it needs to be taken further:

> Engineering forms part of a complex mix of social, political and economic developments. We are involved with serious problems at a local and Global level that affect our society and the environment. Perhaps if engineers could study more about the social, economic and political context of their profession they might apply their creativity to employ what the scholars and practitioners in other fields have been discovering. We hope that engineers might then work together with the future graduates of sociology and political economics and with the broader communities in order to redefine engineering practice.

> Understanding the "social impact" of our engineering is not as simple as exploring the potential health and safety risks, or ensuring that we are legally covered for liability. In whatever way is possible, we need to ensure that procedures are in place to critically examine our own engineering practices and study the implications of such practices on local and global societies. (pp. 63-64)

The essence of Baillie's argument is the idea that engineers should be encouraged to develop their critical thinking abilities. Here, critical thinking does not refer to thinking rationally and logically, but to the ability to see beyond what is considered "common sense" understandings of the world. In one sense this is similar to how students in physics, in order to understand Newtonian mechanics, need to let go of everyday "common sense" Aristotelian understandings of mechanics. However, the "common sense" discussed here is tied to the (often unspoken) social relations that constitute and govern much of human existence. While students in a selection of fields are trained to develop this kind of thinking, engineering students are often not given the opportunity to do so. C*ritical pedagogy* is an educational tradition dating back to Paulo Freire (1970) that is dedicated to helping students develop their ability to think and reflect critically. In this dissertation student learning is explored in three courses, which aimed to encourage engineering students to develop their critical thinking abilities. Each of the three courses were, to varying degrees, inspired by critical pedagogy or similar educational traditions. In addition, each course did, in different ways, tie into issues related to social justice.

Social justice is a complex term that has come to hold multiple meanings, but at its core it concerns resisting and reversing oppressive and/or unequal relationships both in terms interpersonal relationships and distribution of resources. In order to address problems of poverty and environmental degradation an appreciation of social justice is needed. An example related to engineering, is the increasing trend of what Schneider, Lucena, and Leydens (2009) refer to as "engineering to help" (ETH), in which it is common that engineers or engineering students from the Global North go to "developing" countries in the Global South in order to help. Schneider et al. observe that there is a growing interest in ETH as an educational approach, but warn that:

> If we do not critically engage the history of development, with its colonial and post-colonial implications, including its omissions and failures, we risk repeating the most serious errors of development ... That is, we risk doing more harm than good, despite our best intentions. Our students have much to gain from ETH initiatives, and the recipient communities much to lose. (p. 47)

This is a clear case where engineering and social justice intersect and with increased globalisation and a growing need to address the aforementioned challenges of poverty and environmental sustainability, this will happen with increasing frequency. Therefore, there is a perceived need to educate engineers regarding social justice (e.g., Baillie & Catalano, 2009a, 2009b, 2009c; Reader, 2006; Riley, 2008c). One way of doing this, which is put forward in this dissertation, is to encourage engineering students to adopt social justice as a critical lens to their practice and profession. However, this has been observed to be challenging for many students.

The genesis of this dissertation occurred when the course instructor (also supervisor of this project) of one of the courses studied, observed that her students, when attempting to approach social justice, appeared to move into what Meyer and Land (2005) refer to as a *liminal space*, which is a "space" of uncertainty, flux, and transition between two different states of knowing, being, or seeing. Some students were able to apply a critical social justice lens in discussions and assignments, i.e., they were able to pass though the liminal space and were able to reach the desired course outcomes. Other students had difficulty changing how they thought about engineering and technology and to adopt alternative views and can be said to have gotten stuck in the liminal space. Yet others (the majority) tried different ways of approaching adopting social justice as a critical lens and can be said to have been moving back and forth in the liminal space uncertain of how to pass through. Clearly for most students in the class it was not trivial to start thinking about engineering in terms of social justice. Drawing on Meyer and Land's (2003) emerging framework of threshold concepts—in which the assumption is made that in most, or perhaps all (disciplinary) knowledge domains, there exist certain concepts that serve as gateways to further progress as a learners and a deeper levels of knowledge—it was hypothesised that for engineers, both practising professionals and students, adopting a socially just perspective to their practice and profession could be seen as a threshold that needs to be crossed and that this transition might prove both transformative and troublesome. This hypothesis is explored in this dissertation.

While the ideas of crossing a threshold and navigating a liminal space were useful for framing the research project, an approach was needed for the inquiry, and inspiration was drawn from the phenomenographic research tradition (e.g., Marton and Booth, 1997). Phenomenography is based on the assumption of a non-dualist position (where different experiences or conceptions are neither psychological nor physical—not located in the subject or in the world, but between these two), and facilitates the creation of an "outcome" space of shared conceptions of some phenomenon. In the methodology adapted for the research project the threshold concepts and phenomenography frameworks were combined to create a conceptual model suited to frame the student learning experiences under study.

The aim of the research presented in this dissertation was to investigate how successful emerging educational efforts concerned with engineering and social justice, as the course mentioned above, are in helping students approach adopting social justice as a critical lens, or in a somewhat wider sense develop critical thinking in areas related to social justice and engineering. In addition, the ambition was to discern those aspects of existing practice which are essential in helping students cross the hypothesised threshold, as well as to identify ways in which practice can be improved, in order to contribute to building pedagogical capacity in this emerging area for the benefit of future students. The following three questions guided the inquiry:

- How can students be encouraged to adopt a social justice lens toward their practice and profession?
- What are the ways in which students vary in their approach to taking a socially just perspective to engineering?
- What is the variation between courses that take slightly different approaches to a similar goal of encouraging students to develop their critical thinking abilities?

Furthermore, the research presented in this dissertation contributes to the emerging threshold concept framework by raising the notion of the existence of thresholds for a whole discipline, e.g., social justice in engineering. Hence, the title of this dissertation is: *Seeing Through the Lens of Social Justice: a Threshold for Engineering*.

To conclude, this dissertation is part of an educational effort aimed at helping prepare students—by encouraging them to broaden their horizons and develop their abilities to think and reflect critically—for the challenges and opportunities they will face in their future careers in an increasingly globalised and changing world and to ensure that the impact of engineering in this world is a positive one.

The Structure of the Dissertation

This dissertation is broken down in the following way:

In **Chapter 1** the growing awareness, within engineering, of the need to acknowledge the social impact of engineering is discussed along with some engineering educators and practicing engineers who suggest that the current efforts need to be taken further by emphasising critical thinking and social justice. It is acknowledged that this appears to be difficult for some engineering students to do and the notion of a social justice threshold is introduced.

In **Chapter 2** the range of conceptual frameworks needed to situate and frame the study are introduced and reviewed. First, the stage is set through a discussion of the natures of engineering and social justice and how they can come together. In addition, several other approaches aimed at addressing the social impact of engineering are identified and differentiated from approaches focused on engineering and social justice. Then, common educational frameworks currently used in engineering education as well as alternative frameworks, such as critical pedagogy and transformative learning theory, are reviewed. To frame and support the idea of social justice as a threshold for engineering the ideas of thought collectives and hegemony are introduced. In addition these conceptual constructs serve as a bridge between the current incarnation of engineering education and one that emphasises critical thinking to a greater extent. Lastly, to frame the research study, educational research in higher education and engineering education is discussed and frameworks such as threshold concept theory and phenomenography are introduced and overviewed.

In **Chapter 3** the frameworks introduced in Chapter 2 are brought together and operationalised into the methodology and method used to guide the inquiry of the research project. In this chapter the genesis, hypothesis, methodology, method, and progression of the research project are discussed.

In **Chapter 4** the study, carried out during the winters of 2008 and 2009, of student learning in the course *Engineering and Social Justice: Critical theories of technological practices* is discussed. First, the context, thematic and practical aspects of the course as well as the research approach used are described. Then, the findings are presented in the form of a liminal outcome space for social justice and emerging perception shifts of engineering among the engineering and social science students in the class. The chapter is concluded with a summary and some reflections.

In **Chapter 5** the study, carried out during the fall of 2008, of student learning in the course *Sustainable Design Politics and Culture* is discussed. First, the course, its context, and the research approach used are described. Then, the findings of the study are presented in the form of outcome spaces for sustainability and social justice and observations about the relationship between these two terms as well as the role of critical thinking in the course. The chapter is concluded with a summary and some reflections.

In **Chapter 6** the study, carried out during the fall of 2008, of student learning in the course *Science, Technology, and Ethics* is discussed. First, the course context and scope, the role of social justice, and the research approach deployed are described. Then, the findings of the study are presented as an outcome space for social justice and observations about the role of critical thinking in the course. The chapter concludes with a summary and some reflections.

In **Chapter 7** pedagogical implications of the three studies presented in Chapters 4-6 are discussed. The main body of the chapter constitutes an overview and comparison of deferent key pedagogical characteristics of the three courses studied. The chapter is concluded with a summary and some reflections.

In **Chapter 8** the different threads running through this dissertation are drawn together. In this chapter, a more holistic perspective is adopted and the discussion is broadened by comparing and contrasting the diffident studies. In addition, the nature of the data and outcome spaces, the research process, the conceptual model developed and utilised, and the implications of the findings are explored and reflected upon.

In **Chapter 9** the themes discussed throughout the dissertation are brought together in a summary and conclusions.

In **Chapter 10** three areas of future work are outlined: 1. To use the findings of this project to help redesign courses or to create new ones, as well as using variation theory (Marton & Tsui, 2004) as a basis for the adoption of the results as input to class discussion, in existing or new courses. 2. To further develop the conceptual model put forward in this dissertation in more non-linear terms by drawing on the work of Gilles Deleuze and Félix Guattari (1987). 3. To explore the underpinnings of the emerging threshold concepts framework in relation to dominant disciplinary ways of thinking by drawing on the work of Michel Foucault (e.g., 1980).

Notation used throughout the Dissertation

The following notation has been used throughout the dissertation:

E&SJ refers to the course *Engineering and Social Justice: Critical theories of technological practices*

SDPC refers to the course *Sustainable Design Politics and Culture*

STE refers to the course *Science, Technology, and Ethics*

Queen's refers to Queen's University in Kingston, Ontario in Canada

RPI refers to Rensselaer Polytechnic Institute in Troy, New York in the United States

Smith refers to Smith College in Northampton, Massachusetts in the United States

QS# represents a Queen's University student interviewed in 2008

QSR# represents a Queen's University student self-reflection from 2009

QCRE# represents a Queen's University critical response essay from 2009

RS# represents a Rensselaer Polytechnic Institute student interviewed in 2008

SS# represents a Smith College student interviewed in 2008

I: refers to me as interviewer

STE_I refers to the course instructor of STE

SDPC_I refers the course instructor for SDPC

Publications Generated by the Research Project

At the time of writing the work reported in this dissertation has resulted in four published or submitted manuscripts:

- Kabo, J., & Baillie, C. (2009a). Seeing through the lens of social justice: a threshold for engineering. *European Journal of Engineering Education*, *34*(4), 315-323.
- Kabo, J., & Baillie, C. (2009b). Socially just engineering education: How do we get there? Manuscript submitted for publication in *Engineering Studies*.
- Kabo, J., & Baillie, C. (2010). Engineering and Social Justice: Negotiating the spectrum of liminality. In R. Land, J. H. F. Meyer, & C. Baillie (Eds.), *Threshold Concepts and Transformational Learning* (pp. 303-315). Rotterdam: Sense Publishers.
- Kabo, J., Day, R. J. F., & Baillie, C. (2009). Engineering and Social Justice: How to help students cross the threshold. *Practice and Evidence of the Scholarship of Teaching and Learning in Higher Education*, *4*(2), 126-146.

In addition, the conceptual model proposed in this dissertation has been used to frame service learning in a cross-cultural context:

- Baillie, C., Feinblatt, E., & Kabo, J. (in press). "Whose project is it anyway?" The case of Waste for Life, Argentina. In N. Webster & T. Stewart (Eds.), *Exploring cultural dynamics and tensions within service learning*.

A Note on the Mode of Address Used in this Dissertation

The mode of passive voice has mainly been used throughout the dissertation, but in some instances the pronouns *we* and *I* are used. As this project has been carried out in collaboration with project supervisor Caroline Baillie, the pronoun *we* is used to refer to ideas or observations which have been put forward in material already published, in press, or submitted for publication. The pronoun *I* is used to refer to myself when discussing my role and actions during field work.

A Comment on the Role of the Project Supervisor

As the project supervisor, Caroline Baillie, also was the instructor of the course *Engineering and Social Justice* studied in this PhD project, the question of potential conflicts of interests between these two project roles can be asked. Firstly, while selections of student quotes and the emerging outcome spaces connected to this course were frequently discussed with the project supervisor, this process started after the course had concluded and thus separating the dual roles of the project supervisor as instructor and researcher. In addition, the initial reading of full interview transcripts and preliminary selection of student quotes were done by me with the project supervisor providing a secondary perspective on the choices I made in order to, through an iterative process, clarify and finalise the emerging outcome space in question. Secondarily, at the centre of the project supervisor's educational philosophy are the humbleness, willingness, and ability needed for the critical self-reflection emphasised by Paulo Freire (1970) and other scholars (as discussed in Chapter 2), and as a consequence there is no perceived risk that the data analysis process or the findings could have been influenced by the project supervisor's ego in any way. Indeed, the ambition of this research project, to improve current practice, aligns well with the project supervisor's educational philosophy. Thus, to conclude, no conflicts of interests were experienced in relation to the project supervisor teaching the course *Engineering and Social Justice* and the research carried out on this course.

Chapter 2

Conceptual Frameworks of the Research

In order to explore the issues and questions raised in the preceding chapter a range of conceptual frameworks is needed to situate and frame the inquiry. In this chapter these frameworks are introduced and reviewed. First, the stage is set through a discussion of the natures of engineering and social justice and how they can come together. In addition, several other approaches aimed at addressing the social impact of engineering are identified and differentiated from approaches focused on engineering and social justice. Then, common educational frameworks currently used in engineering education as well as alternative frameworks, such as critical pedagogy and transformative learning theory, are reviewed. To frame and support the idea of social justice as a threshold for engineering the ideas of thought collectives and hegemony are introduced. In addition, these conceptual constructs serve as a bridge between the current incarnation of engineering education and one that emphasises critical thinking to a greater extent. Lastly, to frame the research study, educational research in higher education and engineering education is discussed and frameworks including threshold concept theory and phenomenography are introduced and overviewed.

Perspectives on Engineering

What is engineering?

According to Voland (2004), engineering is both a profession—to be an engineer—and an activity—to engineer. This corresponds to the definition of the term found in the Oxford English Dictionary (n.d.): "**1. a.** The action of the verb ENGINEER; the work done by, or the profession of, an engineer. **b.** The art and science of the engineer's profession." However, how engineering is conceptualised by those in the profession and by those outside the profession goes beyond these brief dictionary definitions. In this section different perspectives of the engineering profession are explored.

A classical definition of engineering was devised by Thomas Tredgold on behalf of the Institution of Civil Engineers in 1828 that states: "[engineering is] the art of directing the great sources of power in nature for the use and convenience of man [*sic*]" (Johnston, Gostelow, & King, 2000, p. 26). A more recent definition of engineering is given by the American Accreditation Board of Engineering and Technology (ABET):

> Engineering is the profession in which a knowledge of the mathematical and natural sciences, gained by study, experience, and practice, is applied with judgement to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind. (in Voland, 2004, p. 2)

The last part of the ABET definition rings very similar to Tredgold's 180 years older version—the purpose of engineers is still to control the forces of nature for the convenience of humans, but now it is to be done economically. Another aspect has also entered the definition, the idea of engineers applying knowledge of mathematics and science to achieve their goals. In Canada the corresponding agency to the ABET is the Canadian Engineering Accreditation Board (2009), which offers the following view of engineering and engineering education:

> The engineering profession expects of its members' competence in engineering, as well as an understanding of the effect of engineering on society. Thus, accredited engineering programs must contain not only adequate mathematics, science and engineering, but they must also develop

> communication skills and an understanding of the environmental, cultural, economic and social impacts of engineering on society and of the concept of sustainable development. (p. 11)

The emphasis here is on the notion that engineers must understand the impacts of their practice on society and the environment which stands in strong contrast to Tredgold's definition, which can be interpreted in a way that nature exists for humans to exploit. However, Johnston et al. (2000) argue that Tredgold captures the idea that engineering should be at the service of humanity and by extending that logic, this is true for the ABET definition as well. According to Schiavone (2002), engineering is: "The practical application of mathematics and science to create, design, test, improve, and develop knowledge, research, money, business, economics, and technology" (p. 18). He then adds: "Engineering is a process that applies mathematics and physical science to [the] design and manufacture of a product or service for the benefit of society" (p. 18). This is similar to Voland (2004), who writes that engineering is: "An innovative and methodical application of scientific knowledge and technology to produce a device, system or process, which is intended to satisfy human need(s)" (p. 2).

Students are clearly influenced by their professors' or society's ways of understanding what engineering is. Schiavone (2002) collected and presented the following quotes of first year students' ideas of engineering:

- A subject that reflects our understanding of thing around us.
- The application of scientific knowledge to solve practical problems.
- The bridge between pure science and practical application.
- The application of [science] to provide goods to satisfy human needs.
- Creative problem solving.

- The use of technology to perform tasks.
- The study of how to build things.
- The study of how things work and how we can make them work better.
- Creating, designing, testing and improving systems.
- A scholarly, yet practical, study of the physical applications of human beings' technology combined with nature's laws.
- A profession by which you utilize mathematical, scientific, and physical knowledge for the betterment of humankind.
- Applying math and science to life.
- The application of the simplest and least costly method to solving a problem.
- Being creative and facing new challenges every day. (pp. 17-18)

Some of the themes that emerge from these students' views of engineering are (listed in order of prevalence in Schiavone's selection): applying science, problem solving, improving things, creativity, meet human needs and improve life, building things, and using technology. These themes are much in line with the ABET definition of engineering. Thinking about engineering's impact on society and the environment is not part of the definition held by this group of students.

Andrews, Aplevich, Fraser, Macgregor, and Ratz (2006) offer yet another perspective:

> An engineer is a person who uses science, mathematics, experience, and judgement to create, operate, manage, control, or maintain devices, mechanisms, processes, structures, and who does this in a rational and economic way with human, societal, and natural resources and constraints. (p. 4)

Burghardt (1995) offers an additional view:

> Engineers are practical people and understand that businesses need to be financially viable to hire and employ engineers, accountants, machine operators, and office workers and that engineers play a unique and fundamental role in the organization. They create and design new products, which must operate correctly and safely, and at a cost that lets the company remain in business. All this is accomplished in the context of being a responsible professional, being responsible to the engineering profession and to society. It is in this area of societal responsibility, where engineers have been active in the past, that renewed activity is needed in the future. (p. 41)

Both of the above definitions have moved away from the ideological emphasis on serving humanity and focus more on the creation of products and processes. The importance of economics in engineering is also highlighted. Burghardt (1995) also emphasises the significance of societal responsibility and points out that improvements are needed in this area. Vesilind (2006) agrees with this sentiment, but suggests that engineers have never been very good at this. According to him, "The engineer is sophisticated in creating technology, but unsophisticated in understanding its application. As a result engineers have historically been employed as hired guns, doing the bidding of both political rulers and wealthy corporations" (p. 283).

In a response to the call for a new morality for engineering caused by an increased awareness of the destruction of the environment, Florman (1976) expresses scepticism toward imposing more ethics and responsibility onto practitioners of the profession. According to Florman, engineering is a moral profession, but questions of responsibility need to be addressed on an individual level and not on a collective level. This is partly due to the difficulty of collectively agreeing on what is morally right. As an example, he brings up the development and construction of weapons—for some engineers these are inappropriate areas of employment, while others see these as the right thing to do based on concerns for national security. Florman also argues that engineering practices need to be steered by the government through laws and taxes, and not through self-regulation within the profession.

Some authors in the social sciences, particularly in the field of STS (Science and Technology Studies) (e.g., Sismondo, 2004) who write about issues related to engineering and technology use the term engineering very infrequently and almost exclusively use the term technology. Baillie and Catalano (2009a) comment that in many of these cases it “appears to be assumed that those that ‘do technology’ are engineers” (p. 17). Williams (2002) observes that: “While ‘technology’ expands its rhetorical reach, that of ‘engineering’ shrinks. Never a glamorous term (though it was a solid one), it is now used more rarely, and mostly in a connection with a specific project or department” (p. 17).

A recurring aspect of how engineering has been conceptualised is as applying science to solve problems. According to Sismondo (2004) the idea that technology is applied science is centuries old, but this notion has been challenged from many directions in more recent times. For example, most historians of technology think that “science owes more to the steam engine than the steam engine owes to science” (Sismondo, 2004, p. 76). According to Sundin (1991) the steam engine was invented long before the laws of thermodynamics were formulated. These laws were actually derived from experiences of operating steam engines so this is an example of science as a result of technology. According to Sismondo (2004), engineering has its own research and knowledge traditions. There are several additional authors who have written about the influence of science on engineering, for example Mumford (1963) and Pool (2003). According to Mumford (1963):

> We have seen how engineering as an art goes back to antiquity, and how the engineer began to develop as a separate entity as a result of military enterprise from the fourteenth century onward, designing fortifications, canals, and weapons of assault. … As the methods of exact analysis and controlled observation began to penetrate every department of activity, the concept of the engineer broadened to the more general notion of technician. More and more, each of the arts sought for itself a basis in exact knowledge. The infusion of exact, scientific methods into every department of work and action, from architecture to education, to some extent increased the scope and power of the mechanical world-picture that had been built up in the seventeenth century: for technicians tended to take the world of the physical scientist as the most real section of experience, because it happened, on the whole, to be the most measurable; and they were sometimes satisfied with superficial investigations as long as they exhibited the general form of the exact sciences. The specialized, one-sided, factual education of the engineer, the absence of the humanistic interests in both the school of engineering itself and the environment into which the engineer was trust, only accentuated these limitations. (pp. 219-220)

In Mumford's view, the European Enlightenment era left an imprint on all disciplinary fields, and the field of engineering was notably influenced. Pool (2003) writes about how this influence has lingered on within the engineering profession, but that it ultimately is a folly. According to him:

> Traditionally, engineers have seen their work in positivist terms. Like scientists, they take it for granted that their work is objective, and that they

> believe that to understand a technology, all one needs are the technical details. They see a strict dichotomy between the pure logic of their machines and the subjectivity and the irrationality of the world in which they must operate. On the other hand, a growing school of social scientists sees technology as socially constructed. Its objectivity, they say, is a myth created and propagated by engineers who believe their own press. As with science, this is no mere academic debate. Our attitude toward technology hinge, in a large part, on what we believe about the nature of the knowledge underlying it. … unlike scientists, engineers are working with a world of their own creation, and the act of creation cannot be understood in positivist terms. (p. 20)

Williams (2002) adds to this debate by stating that:

> There is no "end of engineering" in the sense that it is disappearing. If anything, engineering-like activities are expanding. What is disappearing is engineering as a coherent and independent profession that is defined by well-understood relationships with industrial and other social organizations, with the material world, and with guiding principles such as functionality. Engineering is "ending" only in the sense that nature is ending: as a distinct and separate realm. .... Engineering emerged in a world in which its mission was the control of non-human nature and in which that mission was defined by strong institutional authorities. Now it exists in a hybrid world in which there is no longer a clear boundary between autonomous, non-human nature and human-generated processes. Institutional authorities are also losing their boundaries and their autonomy. (p. 31)

In this new world, engineering cannot be seen as an isolated activity. According to Johnston et al. (2000), a modern definition of engineering is: “A total societal enterprise, with significant influences on all aspects of human life and a major role to play in moving the world towards particular goals” (p. 26). However, this social dimension of engineering and technology appears to be absent from many of the views on engineering presented above. Noble (1984) offers the following insight in why this is so:

> Because of its very concreteness, people tend to confront technology as an irreducible brute fact, a given, a first cause, rather than as hardened history, frozen fragments of human and social endeavour. In short, the appearance here of automaticity and necessity, though plausible and thus ideologically compelling, is false, a product, ultimately, of our own naïveté and ignorance. For the process of technological development is essentially social, and thus there is always a large measure of indeterminacy, of freedom, within it. Beyond the very real constraints of mater and energy exists a realm in which human thoughts and actions remain decisive. (p. xi)

MacKenzie (1989) ties awareness of this social dimension of engineering to success in the profession.

> [S]uccessful engineers also know that, to be successful, they have to engineer more than metal and equations. A technological enterprise is simultaneously a social, an economic, and a political enterprise. … Sometimes, of course, engineers do seek to build their systems only of metal and equations, forgetting the need also to bind in human and organizational allies. These engineers, I suggest, are often those of whom their colleagues say, “X built a

> brilliant so-and-so, but somehow it never caught on; no one was ever interested in it." (p. 198)

Engineering in a social context

As could be seen above with the students' definitions of engineering collected by Schiavone (2002), an influence on engineers' view of their profession is the education that they have experienced. According to Baillie (2006), engineering has often been learnt as if it were isolated from everything else, with a focus on the technical and practical aspects. In other words, students are seldom educated in the context in which they will work as engineers after they graduate despite there being many available studies on the impact of technology and engineering on society (e.g., Franklin, 1999). Ways in which society have impacted technology and alternative views on the ways that technology has influenced the way that humans live are commonplace in the emerging field of Science and Technology Studies (STS). Researchers in this area rarely share their knowledge with engineers, but publish in their own journals and teach their own students. However, in several universities across North America, Europe, and South Africa it is increasingly common to see STS departments, which may be interdisciplinary or hosted within a sociology department, servicing engineering students, for example at Rensselaer Polytechnic Institute in the United States. Johnston et al. (2000) report on the Engineering and Society Programme at McMaster University in Canada which focuses on relating engineering and technology to society. Compared to the usual four years for an undergraduate engineering programme in Canada this programme spans five years. The extra year allows for fitting more material into an already crowded curriculum, and the students get both the technical content of a traditional degree and a broader understanding of the engineering context. There have, however, been few studies and there is therefore little evidence of the success of such programmes in really helping students to transform their perspective. What is needed is an in depth study of the ways in which such courses might impact students' ways of perceiving their role and impact on society.

In recent years there has been more emphasis put on the importance to consider the *social impact* of engineering in North America and elsewhere, and this is now included in the accreditation criteria for engineering programmes. The Canadian Engineering Accreditation Board (2009) says that "accredited engineering programs must ... develop ... an understanding of the environmental, cultural, economic, and social impacts of engineering on society" (p. 11). Its American equivalent uses similar words: "Engineering programs must demonstrate that their students attain … the broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context" (Engineering Accreditation Commission, 2008, p. 2). Despite this well-intentioned movement, there is no attempt to address the challenge of how this understanding is to be developed, nor how social impact analysis is to be done, or learned. In the wake of these new accreditation requirements there has been a growing interest and recognition among engineering educators and institutions for several approaches, such as *service learning*, *social responsibility*, engineering *ethics*, *humanitarian engineering*, and engineering and *sustainability,* which are seen to have the potential to help students develop the desired knowledge and skills. However, there is rarely an attempt to bring in sociologists, political scientists, development studies scholars and others who might be able to help develop knowledge in this area of social impact.

According to Coyle, Jamieson, and Oakes (2005) a central aspect of the idea of *service learning* is that students learn and develop through active participation in an activity that is carried out in and meets the needs of a community. As an engineering example they discuss Engineering Projects in Community Service (EPICS), which was started in 1995 at Purdue University, and argue that such programmes are one way to meet both technical needs in the local community and the educational needs of students. However, as VanderSteen, Baillie, and Hall (2009) point 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. Service learning projects in engineering initiatives are often located in "developing" countries in the Global South where there is an even more serious need for student preparation and reflection before the projects commence (Baillie, Feinblatt, and Kabo, in press). Marullo and Edwards (2000) discuss service learning as one way for universities to form collaborative partnerships with the community to address social, political, economical, and moral ills, but they emphasise the difference between work for social justice and work for charity. While social justice aims to change an unjust structure, charity, whilst necessary and important, provides only a temporary solution that often ends up reproducing the status quo rather than challenging it. Marullo and Edwards stress that it is important to ask who is empowered by work undertaken by students and 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. It is all too easy for them to brush off problems with the excuse that "we can't do anything about that—it's a social problem." Working holistically to address root causes requires an interdisciplinary approach and a shift in the overall perception of what engineers' role might be in such a location.

Social responsibility (often "corporate" social responsibility or CSR) is another term frequently used in the current economic climate. According to Zandvoort (2008), 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. In addition, Catalano and Baillie (2006) suggest that simply having a responsibility is not enough for inducing positive change to how things usually are done and that the term social justice is more adequate.

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 the argument of this dissertation. Catalano (2006) has reviewed many of the current codes of ethics in the United States and reveals that they are lacking in areas relevant to social justice, such as impact on poverty reduction or enhancement. According to Herkert (2005), “Most research and teaching in engineering ethics has had a ‘micro’ focus” (p. 374)—individual decision making. The “macro” focus of societal decisions—the level of concern in this dissertation—is often ignored. Zandvoort (2008) remarks that

> as regards the teaching of the ethical and social aspects of engineering and technology, it is crucial that due attention is given to the organisational, social, legal and political context in which engineers work, to reveal to them the collective or “macro-ethical” issues and problems of their work, and to enable them to evaluate possible solutions and contribute to the solutions. … To put it in a nutshell, doing good works for poor people does not necessarily mean that students will adequately understand the causes of poverty. (pp. 138-139)

However, even where “macro” is in focus, the discussion is still often framed around ensuring no negative impact *after-the-fact*, rather than critiquing the nature of the technical development at source. One example of emerging work that intends to address this latter point is presented by Riley (2008d) who reports on a course she has designed drawing on pedagogies of liberation. This course is further expanded on in Chapter 6.

Yet another growing area is education focusing on *sustainability.* Nieusma (2009) characterises sustainability in the following way:

> The various approaches to "sustainability" typically share two features that [distinguish] the concept from common understandings of the mainstream environmental movement and its (perceived) focus on identifying and publicizing environmental problems. The first distinguishing feature is a *focus on solutions* to environmental problems, or at least interventions intended to ameliorate those problems. The second distinguishing feature is systematic attention to *intersections*, typically the intersections of social, economic, and ecological systems. Combined, these features direct critical attention to both the constraints to and the opportunities for innovation in each of the systems under consideration, which arguably cannot be accomplished effectively entirely *within* any of the existing disciplinary domains but must be addressed *between* or *among* them. In the terminology of sustainable design scholar Ezio Manzini, sustainability requires both a "strategy of efficiency," or doing things better, and a "strategy of sufficiency," or simply doing less, at least in terms of production and consumption of material goods. ... the concept of sustainability serves to reinforce efforts to promote interdisciplinary collaboration and education, surely including undergraduate engineering education. (p. 2)

Nieusma later points out that "the terminology of sustainability is not without shortcomings" (p. 2) and suggests that "for example by putting a particular company's profit margin on equal footing with environmental protection within that company's local or regional context, sustainability may serve to reinforce business as usual" (p. 2). A course which focuses on the culture and politics of sustainable design is reported on in Chapter 5.

The last related area under development at the present time is a focus on what is known as *humanitarian engineering*. Mitcham, Lucena, and Moon (2005) summarise humanitarian science and technology (and by extension, engineering) as follow:

> While advances in science and technology have benefited many people, they have also often increased rich-poor divides, to which specific organizations have tried to respond. Among these, many emphasize science and engineering expertise. Humanitarian science and technology projects, typically operated on a not-for-profit basis, aim either to provide fundamental needs ... when these are missing or inadequate in the developing world, or higher-level needs for underserved communities in the developing world. (p. 949)

There is an increasing interest link between these humanitarian efforts and engineering education, but the designs of such programmes vary widely from non-critical to critical in their consideration of engineering development (Amadei, 2003; Epprecht, 2004; VanderSteen, 2008). An argument against the development of such programmes, from the perspective taken in this dissertation, is that they can leave the impression that all other engineering programmes are "non-humanitarian."

While all of the areas or approaches described above might have the potential to highlight the social impact of engineering and help students develop desired knowledge and skills, they also appear to have drawbacks (e.g., limited focus or lack of critical thinking) if care is not taken by instructors to address these. The position taken in this dissertation, is that development of critical thinking skills needs to be at the centre of any educational effort aimed at addressing awareness of the social impact of engineering, and in an increasingly globalised world it becomes important for all engineering students, across all programmes, to become critical thinkers and to think through the social justice implications of their work.

Engineering and social justice

Other approaches to facilitating a reflective critique of an engineer's role in society emphasise the need to focus on social justice, rather than only "impact on society." Practitioners and researchers in this area argue that engineering will always impact society in a positive or a negative manner, but that it is necessary to examine ways in which the balance can be shifted to a more positive project in the future. Undergraduate courses with this focus have emerged in recent years especially through the "Engineering, Social Justice, and Peace" network which was launched at Queens University in 2004 ("Engineering, Social Justice, and Peace," n.d.). The network has been host to five international conferences and courses are now taught at Smith College, Rensselaer Polytechnic Institute, Binghamton University, and Cascadia Community College in the United States as well as at the University of Western Australia. The National Academy of Engineering hosted their first symposium on Engineering and Social Justice in October 2008.

In order to understand what is meant by social justice in engineering, one needs to examine what is meant by the term social justice. In an extensive review, Riley (2008c) explores a range of perspectives and movements that fall under the umbrella of social justice—ranging from faith traditions and human rights to ecology and critical theories, such as feminism and critical race theory. According to her:

> It is difficult to define the term social justice. It's not that the term is poorly understood; … each of us knows what we mean by it. The problem is that the term resists a concise and permanent definition. Its mutability and multiplicity are in fact key characteristics of social justice. (p. 1)

Social justice is motivated by religion, politics, ethics, feminism, anti-racism and even environmentalism. The origin of the term is attributed to a nineteenth century Sicilian Jesuit priest and has been very important to certain faith traditions such as liberation theology (Riley, 2008c). However, Riley (2008c) suggests that "[no faith] tradition has a complete and unchanging belief system that can lay out values for social justice for all believers in all times and places" (p. 16).

Gewirtz (1998) argues that (social) justice has two dimensions, one distributional and one relational. According to her, discussions of social justice often become synonymous with discussions of how material and monetary resources are distributed in society. A more holistic approach to social justice also reflects the nature of the relationships which structure society. As an example of a holistic synthesis of the two dimensions Gewirtz puts forward Young's (2000) idea of the "five faces of oppression"—*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). Gewirtz agrees with Young that these are all mechanisms of oppression and social injustice and that these need to be addressed and countered when working for promoting social justice. One exception from this is cultural imperialism, which according to Gewirtz does not always need to be rejected since there are minority groups, such as neo-Nazis, that have extreme and oppressive views that should not be affirmed. Gewirtz's discussion of social justice and the five faces of oppression is situated in the context of educational policy research and Gewirtz wonders to what extent educational policies support, interrupt or subvert these mechanisms of oppression and injustice. This discussion is relevant in the context of the current study, however, the focus needs to be on how and to what extent the courses under study do anything support, interrupt or subvert the five faces of oppression.

In addition to codes of conduct and education, workplace culture and climate also influence engineers' view of their profession. According Johnston et al. (2000), the majority of engineers in the United States work for private corporations or as self-employed consultants. Thus, there is a strong link between engineering and private corporations. Baillie (2006) points to the historicity of this link by drawing on Johnston et al. (2000), who state that engineering played an essential role in the great economic growth that led to the rise of industrial capitalism. Corporations are most often driven by a profit motive and hence much engineering has also been profit driven. Although not all engineering is driven by profit, even disciplines that focus more on service, such as civil and environmental engineering, have been affected by the need to compete in the marketplace (Baillie, 2006). Baillie (2006) argues that the more engineering as a profession or an activity becomes synonymous with a profit motive, the more possibilities for alternative visions of engineering diminish. Young engineers who come to work in this type of environment after graduation risk being pushed toward a view of the profession where the focus is on the economic issues at the expense of critiquing the impact of their engineering in a broader context, i.e., they become part of the dominant thought collective (this term will be discussed in detail below). Without an education that encourages critical thinking, as previously discussed, graduates are unlikely to be able to make the connection between their own work and the challenges of poverty and environmental sustainability the world are facing. Williams (2002) develops this argument:

> Engineers evaluated costs in the context of a significant goal: the defence of a democratic society (through economic or military might), or the progress of civilization (cheap power, flood control, less hard labor, better communications). The importance of these goals has not disappeared, but the rhetoric of engineering no longer emphasizes them. Instead, it dwells on

> almost exclusively on technological innovation as an end in itself, with market performance as the measure of success. Compared to the goals of furthering democracy or civilization, the aim of profitable innovation seems considerably less noble. (p. 30)

Engineering is an activity with strong connections to many aspects of human life and Earth's current state; it always exists in a social context and cannot just be seen as solving isolated technical problems. Thus, engineers need to take a broad view to their practice and profession, but as seen above this is not necessarily the case in the current state of affairs. Education, codes of ethics and workplace culture influence how engineers define their profession and selves. Both Baillie (2006) and Catalano (2006) argue that the profit making paradigm is inadequate for dealing with the challenges humanity and engineers now are facing, and therefore a new paradigm for engineering is needed. One such paradigm will be presented in the next paragraph. Since the profit making paradigm is deeply entrenched in the current engineering context, possible steps towards a new paradigm might be an overhaul of engineering education and the present codes of ethics. The call for a new perspective on engineering is reflected in Johnston and al.'s (2000) argument that there is no comprehensive philosophy of engineering (or technology), and that the creation of such a philosophy is important for the future of the profession.

Catalano and Baillie (2006) argue for a new paradigm for engineering that is centred on themes of social justice and peace rather than profit or technical wizardry. According to them the rationality that has ruled Western civilisation and engineering for much of the latter part of history needs to be coupled with compassion. Rationality by itself in not evil, but it offers a limited perspective that has had great consequences both for humanity and the Earth. Reason guided by compassion offers a wider perspective that should prove more beneficial for all of humankind and the Earth. While Catalano and Baillie (2006) express scepticism toward the idea that technological progress can be equated with the progress of the human race, they do not believe that society can go back to an earlier state or that placing restrictions on technological progress is a solution. However, the call for a new engineering paradigm signals that technological progress needs to be better guided.

Catalano and Baillie (2006) do not believe that values based on social justice can be forced upon people; rather they want to broaden how engineering is conceptualised so people can chose a view that is consistent with their own values. However, drawing on Simon's discussion of teaching (1992), engineers should be encouraged to consider what social visions they support by their practices. As an example of an aspect of how engineering can be re-imagined to align more closely with social justice, Catalano (2006) suggests that an engineering design process in addition to the traditional optimisation of a technical solution and more recent ethical considerations, also should involve an evaluation of whether or not the proposed solution helps to reduce the suffering and injustices in the world. If the solution does not contribute towards reducing suffering and injustice it should then be discarded. This is a radical shift away from traditional engineering design. Summary of the four steps of the proposed design algorithm is given below:

- *Via Positiva* [italics added]. The problem is identified, fully accepted and broken down into its various components using the vast array of creative and critical thinking techniques which engineers possess. What is to be solved? For whom is it to be solved?
- *Via Negativa* [italics added]. Reflection on the possible implications and consequences for any proposed solution are explored. What are the ethical considerations involved? The societal implications? The global consequences? The effects on the natural environment?

- *Via Creativa* [italics added]. The third step refers to the act of creation. The solution is chosen from a host of possibilities, implemented and then evaluated as to its effectiveness in meeting the desired goals and fulfilling the specified criteria.
- *Via Transfomativa* [italics added]. The fourth and final step asks the following questions of the engineer: Has the suffering in the world been reduced? Have the social injustices that pervade our global village been even slightly ameliorated? Has the notion of a community of interests been expanded? Is the world a kinder, gentler place borrowing from the Greek poet Aeschylus? (Catalano, 2006, p. 47)

A visualisation of the design process can be found in Figure 1.

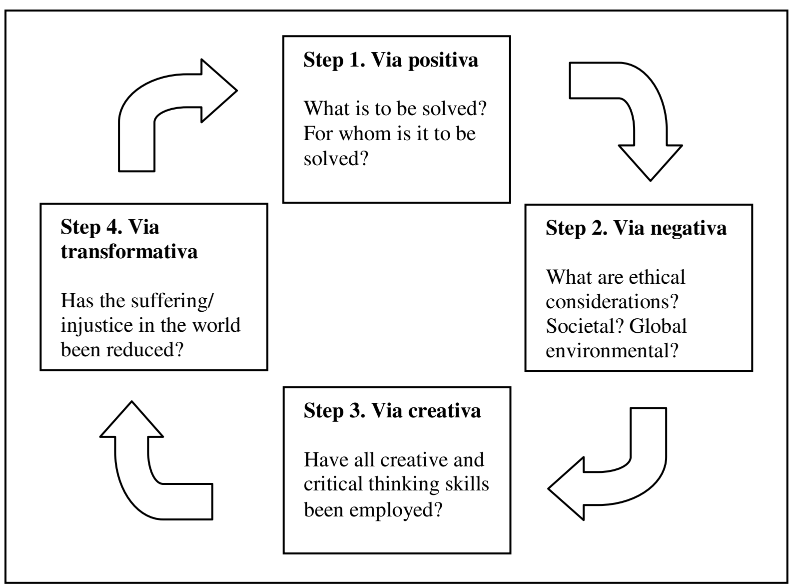

Figure 1: An Engineering Design Algorithm based upon a Morally Deep World (adapted from Catalano, 2006, p.48)

Ursula Franklin (1999) is a key thinker in the area of technology and society. She offers additional advice on how to ensure a socially just engineering practice. A critical question for engineers to ask when considering a particular project, rather than simply consider benefits and costs, is “whose benefits and whose costs?” (Franklin, 1999, p. 124). To help engineers address this question Franklin (1999) has devised a seven point check list:

Does the project:

- Promote justice?
- Restore reciprocity?
- Confer divisible or indivisible benefits?
- Favour people over machines?
- Maximize gain or minimizes disaster?
- Promote conversation over waste?
- Favour reversible over irreversible? (p. 126)

In addition to this Franklin also offers the idea of bookkeeping, but in Franklin’s mind this idea is much broader than traditional economic bookkeeping. She suggests that rather than one book three books are needed: one for economy, one for people and social impacts, and one for environmental accounting. The question “whose benefits and whose costs?” can then be asked in relation to each book.

Engineering Education: Conventional and Alterative Frameworks

The training of engineers has taken different forms throughout history as human societies and civilisations have risen and fallen and the profession itself has evolved. According to Booth (2004):

> Engineering education can trace its origin to two distinctly different roots. The first is the tradesman apprentice education, where boys with indentures to the local trades studied to advance their theoretical and practical knowledge of the tools of their trade. … The other sort of root is the university or college that took the natural sciences as a starting point and specialized in applications to engineering. (p. 10)

According to Booth, Chalmers University of Technology in Sweden and Georgia Institute of Technology in the United States are examples of the first origin, while Massachusetts Institute of Technology (MIT) in the United States is an example of the second. Today all three institutions, as well as Queen's University in Kingston, Canada, are research-led and education-intensive universities that offer a range of programmes of study from traditional disciplines to new and emerging disciplines. However, Booth suggests that the conditions both within which engineering occurs and the context surrounding engineering education are now changing. There are many others who also have written about these changes (e.g., Crawley, Malmqvist, Ostlund, & Brodeur, 2007; Williams, 2002). In the 1996 Review of Engineering Education in Australia it was stated that:

> The Review of Engineering Education is recommending no less than a culture change in engineering education which must be more outward looking with the capability to produce graduates to lead the engineering profession in its involvement with the great social, economic, environmental and cultural challenges of our time. (Institution of Engineers Australia, 1996, p. 1)

In order to address these challenges, the National Academy of Engineering in the United States has recommended that engineering institutions develop more innovative programmes, and have stated:

> The engineering education establishment, for example, the Engineering Deans Council, should endorse research in engineering education as a valued and rewarded activity for engineering faculty as a means to enhance and personalize the connection to undergraduate students, to understand how they learn, and to appreciate the pedagogical approaches that excite them. (National Academy of Engineering, 2005, p. 54)

In a similar vein, the Millennium Project of The University of Michigan in the United States has made several recommendations related to engineering education in a recent report, including the need to:

> Stimulate more activity in the scholarship of engineering education and learning, encouraging investment in research and the adoption of evidence-based approaches to innovation and continuous improvement. (The Millennium Project, 2008, p. 88)

In light of the above, the research reported on in this dissertation may be seen as a contribution to research and scholarship in engineering education. The intention is to contribute to research as well as the practice of engineering education.

Problem solving in engineering education

> We're engineers. Engineers solve problems. In five words, [Provost Robert] Brown … captures the soul of MIT. (Williams, 2002, p. 29)

Problem solving has a central role in engineering and physics education (Bowe, Flynn, Howard, & Daly, 2003), and is considered a key ability for professional engineers (Jonassen, Strobel, & Lee, 2006). However, in recent decades, questions have been raised about the traditional way of training students in problem solving in engineering education through lectures, tutorials, and set problems. This has led to the development and implementation of alternative ways of training engineering students, such as problem-based learning or project-based learning.

Some problems with traditional approaches to teaching problem solving

According to Bowe et al. (2003), learning through problem solving is a well established practice in engineering and physics education. Kim and Pak (2002) support this by saying that problem solving constitutes a major part of most physics classes. Below, some observations on problem solving in the context of physics education are discussed. As problem solving is a central activity in engineering education, these observations should apply to engineering education more broadly.

The conventional approach to problem solving involves presenting material during a lecture, then posing example problems that are solved by the professor or teaching assistants during the tutorials. Finally, students are expected to solve similar problems themselves. Bowe et al. (2003), however, suggest that:

> These problems are narrow in focus, test a restricted set of learning outcomes, and usually do not assess other key skills. The students do not get the opportunity to evaluate their knowledge or understanding, to explore different

approaches, nor to link their learning with their own needs as learners. They have limited control over the pace or style of learning and this method tends to promote surface learning. (p. 742)

According to Thacker, Kim, and Trefz (1994), when traditional problem solving is used in introductory physics classes, many students fail to develop an understanding of the underlying physical concepts if these differ from their initial common sense (mis)conceptions. Despite the fact that students are learning how to manipulate the data correctly, in the numerical sense, and can learn to solve quantitative problems they often do not understand the underlying concepts. Bowden and Marton (2004) conclude, for example, that many students in introductory physics have more of an Aristotelian than a Newtonian understanding of basic mechanics.

Kim and Pak (2002) investigated the idea that this situation might have arisen because the students have not done enough problems. They carried out their study among the first year students in the Physics Education Department of Seoul National University in South Korea. In order to attend higher education in South Korea students are required to take a national examination (Kim & Pak, 2002). To prepare for the physics exam students solve many problems in science and mathematics, usually using commercially available workbooks in addition to work in school. These workbooks consist of three parts: summary of content, example problems with solutions, and practice problems with short answers (Kim & Pak, 2002). The average number of workbook problems that the students in Kim and Pak’s study had solved was about 1500. At the start of the term the researchers tested how well prepared the students were in mathematics and mechanics, and during the term they investigated eventual conceptual difficulties the students might have in basic mechanics. They found that the students were well prepared for solving quantitative problems, but lacked in qualitative understanding of basic concepts in mechanics—such as differentiation between acceleration, force and velocity. Kim and Pak also found little correlation between the number of workbook problems solved and students' conceptual understanding, which suggests that the number of problems solved is not a critical factor for conceptual understanding of physics. Kim and Pak (2002) conclude by saying: "The result of this investigation provides evidence for the limits of traditional problem solving. Although traditional problem solving is an important part of studying to understand physics concepts, some aspects of conceptual understanding might require other approaches" (p. 765).

According to Jonassen et al. (2006), traditional problem solving is not the most optimal way to prepare engineering students for their future workplaces. The kinds of problems described above by Bowe et al. (2003) are well-structured—the parameters are given in the problem statement and there is one correct solution that can be found by applying preferred solution methods (Jonassen et al., 2006). However, workplace problems are not well-structured, but ill-structured. According to Jonassen et al. (2006):

> Ill-structured workplace problem have vaguely defined or unclear goals and unstated constraints; they possess multiple solutions and solution paths or no consensual agreement on the appropriate solution; they involve multiple criteria for evaluating solutions; they possess no explicit means for determining appropriate actions or relationships between concepts, rules, and principles that are used; and they require learners to make judgments and express personal opinions or beliefs about the problem and defend them. (p. 139)

Historically, it has been assumed that learning to solve well-structured problems in the classroom gives the ability to solve ill-structured workplace problems, but recent research indicate that this is not the case (Jonassen et al., 2006).

Problem-based learning

Problem-based learning (PBL) has been proposed and implemented in many universities as an alternative to the traditional preparation of professionals, especially when they are involved in problem solving. It has been particularly successful in the area of medicine but has also been the method of teaching in some engineering schools for 30 years. Bowe et al. (2003) report on how PBL can be used to teach physics to first year engineering students. The focus of their paper is the actual implementation of PBL in two first year physics courses in the Dublin Institute of Technology. According to Bowe et al. (2003):

> PBL is characterised by the organisation of curricula around real-life problem scenarios. The students are presented with these problems and work in groups towards a solution. The students determine their learning issues and develop their unique approach to solving the problem. The members of the group learn to structure their efforts and delegate tasks. Peer teaching and organisational skills are critical components of the process. Students learn to analyse their own and their fellow group members' learning processes and ... must engage with the complexity and ambiguities of real-life problems. (p. 742)

An important question to pose at this point is that despite the PBL approach being quite different from the way in which traditional problem solving is taught, to what extent does it help students grasp difficult concepts. According to Bowe et al. (2003), the evaluation up to the time of the writing of their paper "has shown that the PBL students exceed non-PBL students in their understanding of physics concepts, achievement in standard physics tests, development of key skills, and ability to work in groups" (p. 744). The results from another study where PBL was introduced in a thermodynamics course at Kettering University in the United States indicate that the PBL students performed better on their final exams than students taught in a traditional way (Nasr & Thomas, 2004).

If Jonassen and co-workers' (2006) characterisation of ill-structured workplace problems are compared to Bowe et al.'s (2003) description of PBL, it can be seen that they match quite well. This is not too surprising since "PBL is characterised by the organisation of curricula around real-life problem scenarios" (Bowe et al., 2003, p. 742). Jonassen et al. (2006) agree that converting the curricula of engineering programmes to PBL is one solution for preparing engineering students to become better workplace problem solvers. They continue to say that PBL has been successfully implemented in several engineering programmes around the world, such as at Aalborg University in Denmark and McMaster University in Canada. However, they add that "many PBL experiences do not adequately accommodate the nature of workplace problems in their learning experiences. … all PBL programs should engage students in resolving the complexities and ambiguities of workplace problems more consistently throughout the curriculum" (Jonassen et al., 2006, p. 147). This last statement contradicts how Bowe et al. (2003) describe PBL. Thus, even if PBL is a good candidate to help students prepare for the kinds of problems they will face in their future workplaces, care has to be taken how the problems used in PBL are designed and/or chosen.

Therefore, in traditional instruction in problem solving, students learn by having the material to be learned presented first followed by practicing the problems; in PBL the problems are the starting point and students have to figure out what they need to know to solve them. The two learning processes are summarised and compared in Figure 2.

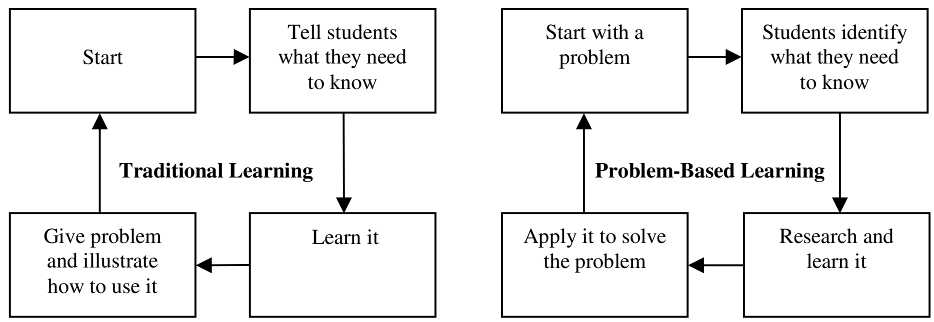

Figure 2: A comparison between traditional learning and problem-based learning (adapted from Nasr & Thomas, 2004, p. 661)

One question concerning problem-based learning is when it is suitable to introduce students to it. According to Bowe et al. (2003):

> There has been reluctance to introduce problem-based learning into first-year physics courses, due to the pedagogical view that the students require a sound body of knowledge and mathematical skills before they are equipped to engage with this process. When [PBL] has been introduced, it has tended to be in the final year of the course. (pp. 742-743)

This point-of-view can also be found in Said et al.'s (2005) proposition of how to implement PBL within the Department of Electrical Engineering at University of Malaya. They suggest that the core subjects in the first year should be taught in a classical framework in order to give the students good theoretical base knowledge. However, Bowe et al. (2003) have shown that PBL can be successfully introduced in the first year of engineering programmes if it is handled properly and the tutors are aware that the students are just beginning their journeys as self-directed learners. Jonassen et al. (2006) bring up the following considerations about implementation of problem-based learning:

> Conversion to PBL requires systemic reform of curricula or at least entire courses. Although they have proven incredibly successful in many contexts, the level of commitment to such an innovation is more than most programs or professors are willing to make. Even if such a commitment is made, PBL programs face the continuous challenge of populating their problem base with authentic problems that are informed by everyday practice. In order to do so, PBL programs need to establish and apply a systematic process of identifying attributes of workplace problems and respond to critical changes in these problems over time. (p. 147)

To summarise, if care is taken to adequately support students in their learning experience and to accommodate the nature of workplace problems, it should be possible to design and implement a PBL-driven curriculum that will successfully address two of the major problems (1. Not helping students to fully grasp fundamental concepts, e.g., basic mechanics. 2. Not preparing students sufficiently for ill-structured workplace problems.) associated with traditional problem solving in engineering education. Also, added benefit from such an implementation are that in addition to problem solving skills, students develop other skills they need as professional engineers, such as communication, teamwork and time-management skills (Said et al., 2005).

Project-based learning

Project-based learning is another approach to teaching and learning that is different from traditional lecture based approaches and problem-based learning. Here follows an overview of three different approaches to project-based learning—case studies, design projects and service learning.

Case studies

Davis and Wilcock (2004) cite several studies that show that students learn more effectively when actively involved in the learning process and that the use of case studies is one way of involving them. They describe case studies in two ways: 1. As complex problems that emphasise both the context and the main point. 2. As student-centred activities that present a situation or topic that raises issues for analysis. Davis and Wilcock (2004) suggest that one of the main advantages of case studies is that they present material in a contextual manner that helps to bring theory and practice together. Much of what Davis and Wilcock say is echoed by Raju and Sanker (1999) who present the following summary of the basic principles behind case studies:

> *The primacy of situational analysis*: Analysis of some specific situation forces the student to deal with [the] "as is" and not the "might be."
>
> *The imperative of relating analysis and action:* The traditional academic focus has been to know; the practitioners' focus has been on action. The case study method of instruction seeks to combine these two activities.
>
> *The necessity of student involvement*: The active intellectual and emotional involvement of the student is a hallmark of case study method. That involvement offers the most dramatic visible contrast with a stereotypical lecture class.
>
> *A nontraditional instructor role*: The instructor's role is not so much to teach students as to encourage learning. His/her role is more of a facilitator and he/she has to be both a teacher and a practitioner.
>
> *The development of an administrative point of view:* The students develop an understanding of the problem from a holistic point of view and not from an

> engineer's perspective alone. (Barnes et al. cited in Raju & Sanker, 1999, p. 502)

Both Davis and Wilcock (2004) and Raju and Sanker (1999) see case studies as a way for engineering education to train students in various professional skills, such as communication. Overall, case studies do not have one tidy and correct answer and students need to make choices. According to Raju and Sanker (1999) this closely reflects reality and is important for preparing students for the workplace.

Design projects – CDIO

In their book *Rethinking engineering education: the CDIO approach,* Crawley et al. (2007) give an overview of and argue for implementation of the Conceive, Design, Implement, and Operate (CDIO) approach to engineering education. According to the authors, CDIO is a response to a concern that engineering education has moved from emphasis on practice to science during the last half-century. This move has meant that more recent engineering graduates excel at disciplinary knowledge, while they have had less training in personal, interpersonal and system building skills. The authors argue for the need for an education that retains the current level of technical knowledge but also strengthen the skills that have been neglected. According to Crawley et al. (2007), the goals of the CDIO initiative are to educate students who are able to:

- Master a deeper working knowledge of technical fundamentals.
- Lead in the creation and operation of new products, processes, and systems.
- Understand the importance and strategic impact of research [and] technological development in society.

To achieve these goals the authors call for more integration between courses in engineering curricula and projects that take students through the same phases as engineering projects in the professional workplace, namely conceiving, designing, implementing and operating a product, process, or system. Each of the phases has a different focus (Crawley et al., 2007). The Conceive phase focuses on what needs to be done and suggestions of how it can be realised. The Design phase creates a design for a product, process, or system that based on the ideas generated in the previous phase is to achieve the desired outcome. The Implement phase transforms the design into an actual product, process, or system, which then is optimised. The last phase, Operate, focuses on the use of the product, process, or system to achieve the wanted results as well as its improvement, maintenance and retirement. The four phases do not necessarily have to be a linear process but can take on a cyclic nature. The authors point out that the terms for the four phases are general in nature, but stress that the phases form the core processes carried out by engineers working to build products, processes, and systems that meet the needs of society. Overall, the CDIO approach to engineering education seems to emphasise the need to prepare students for the real world of the workplace and to meet the needs of industry.

Service learning – EPICS

According to Coyle et al. (2005) a central aspect of the idea of service learning is that students learn and develop through active participation in an activity that is carried out in and meets the needs of a community. The authors cite several reports on service learning being integrated into engineering curricula in various ways. The focus of their paper is on EPICS—Engineering Projects in Community Service—which was started in 1995 at Purdue University in the United States. They summarise EPICS in the following way:

> [EPICS] is an engineering design program that operates in a service-learning context. EPICS students earn academic credit for their participation in the local community. The teams are: *multidisciplinary*—drawing students from across engineering and around the university; *vertically-integrated*—mainly from a mix of freshman [*sic*] through seniors each semester; and *long-term*—each student participates in a project for up to seven semesters. The continuity, technical depth, and disciplinary breath of these teams enable delivery of significant benefit to the community. (Coyle et al., 2005, p. 1)

The authors suggest that programmes such as EPICS are one way to meet both technical needs in the local community and the educational needs of students, especially professional skills such as teamwork and communication which are difficult for the students to learn through lectures.

Comparing the three project-based learning approaches

Case studies, design projects and service learning are three forms that project-based learning can take. They all have their defining characteristics, but also overlap. They can, to some extent, be placed on a continuum with case studies on one end and service learning on the other. Case studies deal with analysing and solving a problem on a conceptual level while service learning can operate on a more practical level. Design projects fall somewhere in between, since they usually involve both a conceptual phase and a more practical creation phase. Service learning can, of course, also involve a conceptual phase—EPICS is a good example—but then again, EPICS combines service learning with design projects. While all three approaches emphasise the development of professional skills, case studies and design projects seem to be mostly geared toward preparing students for the industrial workplace.

Creative problem solving

According to authors, such as Dewulf and Baillie (1999), who promote and develop creative thinking, it is important to ensure that students have the ability to define the problem—to make sure that they focus on the right question. According to Dewulf and Baillie, classically in problem solving—there are four stages: preparation or problem definition, idea generation, incubation (letting the ideas dwell for some time before jumping to conclusions) and verification (testing out the ideas against certain criteria). Dewulf and Baillie suggest that, typically, one is also expected to diverge and converge at different stages of the problem solving process. In the problem definition stage one first diverges—one might ask, “Are we asking the right question? Do we want to build a bridge or a telephone cable? Is the problem transport or communication?” etc. Once this has been decided on, one converges to a specific problem definition. Then one seeks to solve the problem. At this time obvious solutions can be purged so they do not block one’s thinking. Then one can move into idea generation and use any way open to come up with as creative a solution as possible. Dewulf and Baillie emphasise that it is a good idea to have many possible solutions at this point and diverge as much as possible. The ideas are allowed to incubate for some time and finally certain criteria are applied and one converges again to a selected solution.

In helping students to learn how to solve problems, the most commonly neglected of the four phases is the problem definition stage. Even in problem-based learning the problem is often defined for the students. Increasingly, engineering students will graduate and work in a global context. Even small organisations will expect their employees to design for and trade with people from many different countries and cultures. Engineering has the potential to ameliorate many of the emerging problems that humanity faces today including increasing poverty levels, global warming, adequate and available clean water etc. It also has the potential to contribute to the worsening of the current global crises. Students need to become aware of the complexity of the issues that they will face and how engineering relates to these issues. Problem definition becomes even more key when the impact that engineering can have on people's lives begins to be questioned.

Catalano (2006, 2007) elaborates on this further and according to him humanity is facing two major interlinked challenges—the challenge of poverty and under-development and the challenge of environmental sustainability. According to Boff (1997) it is the same logic that has led to the devastation of the environment that lies behind the exploitation of the marginalised. It is also the poor who suffer most from the destruction of the environment (Kanté, 2004). According to Catalano (2006), technology and rapidly accelerating technical advances have played key roles in the creation of these challenges, and consequently, engineers have much to say as to whether or not the challenges of poverty and sustainability can be successfully met. Catalano (2007) highlights the links between engineering and poverty and environmental sustainability in two case studies—one centred on the impact of global warming on the polar bears of the Arctic and one focusing on the role of failing levees in Hurricane Katrina's impact on the poor of New Orleans.

A present and ongoing issue that highlights the importance of problem definition in engineering is the international debate about biofuel (e.g., Connolly, 2008; Monbiot, 2007; Vidal, 2008). Biofuel is an issue that intimately links engineering, poverty and the environment. Biofuels have been seen as a part of the solution of countering global warming since its net carbon dioxide imprint on the environment is zero—a given area of crops will absorb an equal amount of carbon dioxide as that which the biofuel, extracted from the same crops releases into the atmosphere when combusted. Both the European Union and the United States have had an ambition to replace a percentage of their use of fossil fuels with biofuels. As a result, an increasing demand for biofuel in the world has led to farmers switching from food production to fuel production. A decrease in food production will contribute to an increase in food prices, which has the greatest impact on the poor of the world. In addition, production of crops for biofuel has led to the destruction of rainforests in some parts of the world because forest areas are cleared for fuel production. This is an ironic twist since biofuel is considered to be a good thing for the environment. With food prices on a continual increase, the production of biofuel has become a focus for debate. Some of the proponents (e.g., the British Government according to Monbiot, 2007) of continued dedication to biofuel argue that biofuels produced from crops are a necessary step toward a second generation of biofuels created from cellulose.

It is important that engineers become more aware of the impact of their actions and strengthening the problem definition abilities of the profession is a key aspect of this. However, in order to successfully make this shift, engineers need to be humble, self-critical, reflexive, and taking responsibility for their part in the problems whilst realising that they cannot solve all of the world's problems by themselves. Williams (2002) has the following to say about engineers:

> Do [engineers] solve problems? The big problems of the world—a list that commonly includes the fragility of public health systems, globally transmitted epidemics, international criminal networks, disappearing species, terrorism, the global arms trade, and the status of women (and not just in science)—are far too big for engineers to solve by themselves. Engineers may make useful contributions, but they may also be less than useful if they are implicated in causing these problems in the first place, or if they seek tidy solutions when there are none. (pp. 29-30)

It is important to seek a balance between those engineers who take no responsibility and believe that the world's problems have nothing to do with them and who do not seek out the various long term impacts of the technology they create, and those who feel they may solve any problem—without first fully defining it nor seeking input into the definition by those most affected.

Despite a growing awareness of the issues raised above, Seron and Silbey (2009) highlights the difficulties related to the nature of accreditation requirements facing new and innovative initiatives in engineering education. Seron and Silbey (2009) summarise the findings of a study they carried out in relation to this in the following way:

> Cycles of reform have been a constant feature of engineering education [in the United States]. This study suggests that these cycles are endemic because engineering begins with a particularly instrumental conception of responsible preparation. The instrumental logic of engineering repeatedly undermines educational reforms seeking to cultivate the capacities for discretionary interpretation and judgment at the root of professional practice. Using interviews with faculty at two new engineering colleges in the United States, we show how this instrumental logic once again leads to retreat from educational reform. Beginning with criticisms of engineering's failure to produce innovative and socially responsible engineers, new engineering schools [Franklin L. Olin College of Engineering and Smith College's Picker Engineering Program] attempted to address directly the limitations of instrumental rationality by creating curricula that would immerse students from the very outset of their engineering education in the ambiguous work of client-defined problem-solving. Rather than begin with the expertise grounded in mathematics and science and then teach how to apply that knowledge

> through known techniques, both programs asked students to become inquirers seeking knowledge, rather than implementers applying knowledge. As the programs sought legitimacy for their innovations through professional accreditation, however, the open-ended, exploratory processes of serendipitous learning were instrumentalized into a set of measurable procedures for acquiring standard, scientific expertise as the essential credential of the responsible engineer. (p.101)

In the light of Seron and Silbey's study it becomes important to consider the thought collective of engineering and what is considered "common sense."

Critique of common sense views of engineering

It can be argued that, as within any community of practice, 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. Students and engineers today largely work within, and unquestioningly contribute to, the policies and agendas of the socially accepted neoliberalist (Riley, 2008c), pro-development (Ferguson, 1990) standpoint. This perspective 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 one is 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, one needs to understand how these common sense views of engineering are developed and attempt to deconstruct them. Only then one is in a position to help students question the real “cost” and “benefits” and “for whom” of current developments (Franklin, 1999). These ideas can be framed with Fleck’s (1979) work on *thought collectives*. A thought collective, according to Fleck, is “a community of persons mutually exchanging ideas or maintaining intellectual interaction” (1979, p. 39), and furthermore:

> The concept of the thought collective, as we use it to investigate the social conditioning of thinking, is not to be understood as a fixed group or social class. It is functional ... rather than substantial, and may be compared to the concept of field of force in physics. (p. 102)

People can belong to many different thought collectives, but according to Fleck (1979):

> 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. (p. 42)

Fleck argues that stable thought collectives form around organised social groups (such as professional engineers), and “[if] a large group exists long enough, the thought style becomes fixed and formal in structure” (1979, p. 103). He also argues that “the longer a thought has been conveyed *within the same thought collective*, the more certain it appears” (Fleck, 1979, p. 106).

Polanyi is best known for his ideas about *tacit knowing* by which “we can know more than we can tell” (1966, p. 4). While Polanyi seems to have been more interested in the act of knowing rather than the nature of knowledge itself, others have used his ideas to focus on the latter by discussing tacit knowledge. One such example is Meyer and Land (2003) who identify tacit knowledge as one of the different forms of troublesome knowledge relevant for their threshold concept theory which will be described in more detail below. In their work, they develop the idea that students find thresholds in their learning and tacit knowledge becomes a barrier and one potential cause of these, to the uninitiated novice. They link tacit knowledge to Wenger's (1998) ideas about communities of practice; for example, different disciplinary communities have their own shared, unspoken understandings and ways of doing things.

Both Fleck and Polanyi hint at dominant ways of seeing or understanding the world within a given community of practice or thought collective. Gramsci (1971) calls this *hegemony*, or what seems *common sense* to a community.

> [It] is not a single unique conception, identical in time and space ... Its most fundamental characteristic is that it is a conception which, even in the brain of one individual, is fragmentary, incoherent and inconsequential, in conformity with the social and cultural position of those masses whose philosophy it is. (p.419)

Hoare and Smith (1971) elaborate on this by saying that common sense "is used by Gramsci to mean the uncritical and largely unconscious way of perceiving and understanding 'common' in any given epoch" (p. 322). Hegemony, then, is "a process of social control that is carried out through the moral and intellectual leadership of a dominant sociocultural class over subordinate groups" (Darder, Baltodano, & Torres, 2009, p. 12) and "[t]he hegemonic sense of the world seeps into popular 'common sense' and gets reproduced there; it may even appear to be generated *by* that common sense" (McLaren, 2009, p. 67). Thus, the "common sense" which a group of people share and understand is of course not at all "common" to everyone. According to Simon (1992, p. 21): "[E]xisting, taken-for-granted 'ways of life' are value-laden human constructions and thus open to critique." In a similar vein, Foucault spoke of a "regime of truth," "a set of values and beliefs expressed in a discourse that maps out what can—and cannot—be said" (in Somekh & Lewin, 2005, p. 2).

In previous publications (Kabo & Baillie, 2009b, 2010), we have argued that engineering may be considered a particular community of practice, with an associated common sense and thought collective. If engineers blindly accept, and do not question the "common sense" that they work within, they will be part of a thought collective that they were not even aware of. All too often engineers are not in a position to do this critical questioning as they did not learn the skills in school. Simon (1992) expands on the role of education in relation to this:

> [If] education is to be a resource for a process through which individuals attempt to become subjects of their own experience, pedagogical practice must find ways of addressing not only the enchantment of an individual's potential for the acquisition of skills and knowledge, but as well the development of resources within which people can begin to challenge and transform those relations which structure the available opportunities from which to choose. (p. 19)

To help develop programmes for facilitating critical thinking in engineering students, inspiration can be drawn from key scholars in the area of *critical pedagogy*.

Freire and critical consciousness

Paulo Freire has been a key influence for most critical pedagogues. His work stems from the perceived need to develop a theoretical framework to support educational practice for a less oppressive society. Here it is important to note that Freire is not the only scholar who has had concerns in this area. The critical theorists of the Frankfurt School, such as Theodor W. Adorno, Max Horkheimer, and Herbert Marcuse, are examples of others who have been important for the development of scholarship in this area (Arato & Gebhardt, 1982; Darder et al., 2009). However, in the context of North America, Freire has been very influential. As the PhD project discussed in this dissertation was carried out within this North American context and two of the instructors of the three courses studied explicitly expressed being influenced by Freire and critical pedagogy, critical pedagogy, and Freire in particular, was chosen to help frame the courses and student experiences studied.

In his seminal work *Pedagogy of the Oppressed* from 1970, Freire put forward the core of his framework—what he calls *conscientização*, which "refers to learning to perceive social, political, and economic contradictions, and to take action against the oppressive elements of reality" (2003, p. 35, translator's note). In English the term becomes conscientization, or the process of developing a critical consciousness (Darder et al., 2009). Freire (2003) differentiates between what he calls *banking* and *problem-posing* education. Banking education "becomes an act of depositing, in which the students are the depositories and the teacher is the depositor" (p. 72). The relationship between teacher and students is clearly hierarchical and "knowledge is a gift bestowed by those who consider themselves knowledgeable upon those they consider to know nothing" (p. 72). Banking education is not a way to help students develop a critical consciousness, but rather serves to preserve the status quo. Problem-posing education, on the other hand, aims to break the hierarchical relationship between students and teacher and is a vehicle for developing a critical consciousness. According to Freire (2003), in the problem-posing "classroom:"

> The teacher is no longer merely the-one-who-teaches, but one who is himself taught in dialogue with the students, who in turn while being taught also teach. They become jointly responsible for a process in which all grow. In this process, arguments based on "authority" are no longer valid. (p. 80)

This growth process takes the form of respectful and non-oppressive dialogue that aims to help

> … people develop their power to perceive critically *the way they exist* in the world *with which* and *in which* they find themselves; they come to see the world not as a static reality but as a reality in process, in transformation. (p. 83)

However, in relation to the idea of using dialogue as a pedagogical tool Day (in Baillie & Catalano, 2009a) differentiates between taking a position and merely stating an opinion.

> An opinion is not necessarily informed by any knowledge of the matters upon which one is opining. Anyone can have an opinion about anything. Opinions cannot be refuted, i.e., they can contradict other opinions without difficulty since there is no shared basis for discriminating between them.
>
> Taking a position, on the other hand, means having at least some knowledge of that about which one is speaking, and especially of what others have said in the past, and are saying now. We could say that taking a position means precisely showing that one knows what other positions have been, are being, and could be taken. This shared background is what makes it possible for positions to be compared, contrasted, and evaluated. (p. 10)

A key concern in Freire's work was the role of the oppressed in society. Central to his reasoning is that any true change toward a less oppressive society has to start with the oppressed. According to Freire (2003), people belonging to oppressive groups cannot do this and any attempts either end up preserving the status quo or creating new oppressive relationships or at best this comes across as charity. Freire was (initially) working with a class perspective that is clearly still very important today; however, his work has been used to consider various forms of oppression and the approaches that education can take to empower.

When the term "critical thinking" or "ability to think critically" is used in the context of engineering, it is often assumed to refer to thinking *clearly and rationally* (Cederblom & Paulsen, 1991). This can actually result in the opposite of what is intended in the courses studied in this dissertation, as what is *rational*, is often bounded within what is *common sense* within a given thought collective. For example, Day (in Baillie & Catalano, 2009a, p. 10) argues that the statement "Everyone needs a job so they can buy things" might seem a "logical" conclusion within the hegemony of what seems common sense to neoliberal capitalism, but in fact, it can be critiqued from several angles, such as Marxism, feminism, anarchism, and post-colonialism. Day gives the following examples of such critiques applicable to the statement:

> - It takes for granted the existence of a capitalist economy, in which individuals and communities are separated from the means of meeting their needs directly, and thus are forced to go through the mediation of corporations and markets.
> - Even within capitalism, it ignores the many possible ways in which one can meet one's needs outside of the money economy, e.g., through delinking, local barter systems, and so on.
> - It reinforces capitalist individualism and consumerism.
> - It fails to consider the needs of those who cannot work for reasons beyond their control. (in Baillie & Catalano, 2009a, p. 10)

Emerging from critical theory, the term critical thinking takes on a different and more urgent meaning—the ability to see beyond what is considered to be "common sense." Progressive educator bell hooks (1994) 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" (p. 202). As an example, hooks (2003) reflects on progressive education:

> Progressive professors did not need to indoctrinate students and teach them that they should oppose domination. Students came to these positions via their own *capacity to think critically* [italics added] and assess the world they live in. Progressive educators discussing issues of imperialism, race, gender, class, and sexuality heightened everyone's awareness of the importance of these concepts (even those individuals who did not share our perspective). That awareness has created the conditions for concrete change, even if those conditions are not yet known to everyone. (p. 8)

In addition, hooks argues that her experience as an educator has shown her "how easy it is for individuals to change their thoughts and actions when they become aware and when they desire to use that awareness to alter behavior" (p. 39). Her key point is that "where there is consciousness there is choice" (p. 39).

While awareness might be a necessary condition for change, one needs to remember that, for Freire, *conscientização* had two dimensions: to come to see and to take action. "Again and again Freire has had to remind readers that he never spoke of conscientization as an end itself, but always as it is joined by meaningful praxis" (hooks, 1994, p. 47). Carr and Kemmis (1986) point out that "a process of critique can transform consciousness (ways of viewing the world) without necessarily changing practice in the world" (p. 144). 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” (p. 144).

Another way to think about critical consciousness and critical thinking is the use of a critical lens for looking at the world. According to Riley (2008c), “Marx and Engels introduced the idea of class struggle as a critical lens for interpreting historical and current events, emphasizing the importance of understanding structural forms of oppression” (p. 6). In this dissertation, the idea of using social justice as a critical lens for engineers to look at their practice and profession is explored.

To conclude, in order for students to begin to define problems and solve problems, whether locally or globally, they need to be able to take a critical perspective and to question the “common sense” of their own assumptions when dealing with people from very different backgrounds to their own. It is important for them to question even the very essence of what they assume engineering to be.

Transformative learning theory

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 develop understanding of this key educational issue guidance can be drawn from “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. (Mezirow, 2000, p. 8)

Mezirow discusses three related meaning structures—frames of reference, habits of mind and points of view—which he defines in the following ways:

> • A frame of reference is a "meaning perspective," the structure of assumptions and expectations through which we filter sense impressions … [It] is composed of two dimensions, a habit of mind and resulting points of view. (pp. 16-17)
>
> • A habit of mind is a set of assumptions—broad, generalized, orienting predispositions that act as a filter for interpreting the meaning of experience … [It] becomes expressed as a point of view. (pp. 17-18)
>
> • A point of view comprise clusters of meaning schemas—sets of immediate specific expectations, beliefs, feelings, attitudes, and judgements—that tacitly direct and shape a specific interpretation and determine how we judge, typify objects, and attribute causality. (p. 18)

Who people are is closely associated with the frames of reference they hold and changing or transforming these is often non-trivial. For Mezirow (2000), critical reflection is the key to any significant shifts of frames of reference. However, he points out that "[s]ubjective reframing commonly involves an intensive and difficult emotional struggle as old perspectives become challenged and transformed" (p. 23). Therefore, it is important for educators to recognise the importance of a supportive environment to facilitate critical reflection and acting on any insights gained (Mezirow, 2000).

Educational Research

Overview of educational research in higher education and engineering

In this section an introduction and overview of educational research in higher education in general and engineering education in particular is given. According to LeBold (1980), in the 1980s research in engineering education in the United States "often centered around national studies conducted in response to demands for examining engineering education in terms of contemporary practices and anticipated changes and social demands" (p. 406). The focus of engineering education research was on parallel national and institutional efforts to collect, analyse, and synthesise information in four areas—students, faculty, curriculum and instruction, and systems (LeBold, 1980). Regarding engineering students, the research focused on assessing students' abilities and performance; retention of students in engineering programmes; and surveying employment, salaries and further education of engineering graduates. For faculty the focus was on providing opportunities for contained growth and development. Regarding curriculum and instruction researchers focused on the impact of computers, instructional methods and student evaluation. Research on what LeBold refer to as systems involved enrolment to engineering programmes, degrees granted, employment, and professional activities. Overall, in most of the studies LeBold surveyed quantitative research approaches appear to have been used. Jesiek, Newswander, and Borrego (2009) trace latter developments and observe that:

> While the "Neal Report" [from 1986] had suggested that research could improve teaching and learning in engineering and other STEM disciplines, renewed emphasis on the concept of "scholarship" in the 1990s likely had an even greater impact on engineering education. Boyer's *Scholarship Reconsidered* (1990) was especially influential. In addition to expanding the

definition of scholarship beyond traditional research (or “discovery”) to include teaching, application, and integration, Boyer helped promote a national, cross-disciplinary dialog about how the “scholarship of teaching and learning” could enhance the quality of U.S. higher education. (p. 40)

According to Streveler and Smith (2006) engineering education research has gained momentum in recent years and more people have moved into this disciplinary area to conduct research. Jesiek et al. (2009) have the following to say about some of the underlying motivation and intentions: “Our data reveals that while some participants embraced a new research mission for the field, many others held a more traditional reform- and practice-oriented view, linked to a desire for the widespread improvement of engineering teaching and learning” (p. 39). One issue with newcomers to the field is that educational research is quite different from scientific and engineering research and many engineering faculty who want to do educational research do not have the needed knowledge and training to carry out rigorous research (Streveler & Smith, 2006). According to a report from the National Research Council (NRC) U.S. (in Streveler & Smith, 2006), scientific or rigorous research in education (including engineering education) should:

1. Pose significant questions that can be answered empirically
2. Link research to relevant theory
3. Use methods that permit direct investigation of the question
4. Provide a coherent and explicit chain of reasoning
5. Replicate and generalize across studies
6. Disclose research to encourage professional scrutiny and critique (p. 103)

Streveler and Smith (2006) offer three recommendations for how people wanting to conduct engineering education research can meet the NRC guidelines for rigorous research:

> [**1.**] The *purpose* of engineering education research needs to extend beyond an interest in improving an individual's teaching, or developing a specific curriculum. In order to begin to answer fundamental questions about how students learn engineering, engineering education research must take a broader, "big picture" view, which may well include studies conducted outside of the classroom.
>
> [**2.**] In order to increase significance and generalizability of engineering education research, the work must be tied to the appropriate educational, psychological, or sociological *theory.* Faculty who wish to engage in rigorous research in engineering education need to become familiar with this literature or, better yet, partner with psychologists, education researchers, or other social scientists, who can provide guidance on which conceptual framework might be most appropriate for the question being asked. When true collaborations between engineering faculty and learning and social scientist are formed, research in engineering education can *contribute* to learning theory, not only be informed by it.
>
> [**3.**] Faculty should know that the methods of educational research are often different from the *methods* of engineering research. … thus engineering methods will not always work when answering educational questions. Faculty should get guidance on the appropriate measures to use to answer a particular question. (p. 104)

While formalised educational research might be a relatively new phenomenon in the field of engineering, it has been performed in other disciplinary fields for a long time, for example science education became a separate research discipline in the 1970s (Fensham, 2004). Johnson and Christensen (2008) gives an overview of the three general approaches used in educational research—the qualitative approach, the quantitative approach and the mixed approach. Each of these three serves as an umbrella for research approaches and methods that share some central characteristics. The qualitative and the quantitative approaches are polar opposites while a mixed approach—as the name suggests—merge characteristics from the other two. An overview and comparison of the three approaches can be found in Table 1. According to Johnson and Christensen (2008) quantitative approaches dominated research for most of the last century, while qualitative approaches first became seen as respectable alternatives during the 1980s. Mixed approaches have only gained real legitimacy in recent times, but have been used by practicing researchers throughout the history of research. Borrego, Douglas, and Amelink (2009) report on the type of research approaches preferred by engineering education researchers:

> While examples of all three approaches do exist within the pages of [the Journal of Engineering Education], the empirical results for an engineering education conference described here show that they are not being used equally. There appears to be a trend towards the use of quantitative methods, and even within the quantitative area only certain approaches are deemed to be worthwhile. (p. 63)

Borrego et al. comment that due to the range of issues unexplored within engineering education they expected all three approaches to be represented in their study. Due to the subjective nature of the type of intimately personal learning experiences explored in this dissertation, i.e. adopting social justice as a critical lens, a quantitative research approach is not suitable, but rather a qualitative approach is needed.

	Quantitative Research	Mixed Research	Qualitative Research
Scientific method	Confirmatory or “top-down” The researcher tests hypotheses and theory with data	Confirmatory and exploratory	Exploratory or “bottom-up” The researcher generates new hypotheses and grounded theory from data collected during fieldwork
View of human behavior	Behavior is regular and predictable	Behavior is somewhat predictable	Behavior is fluid, dynamic, situational, social, contextual, and personal
Most common research objectives	Describe, explain, and predict	Multiple objectives	Explore, discover, construct and describe
Focus	Narrow-angle lens, testing specific hypotheses	Multilens focus	Wide-angle and “deep-angle” lens, examining the breadth and depth of phenomena to learn more about them
Interest	General laws	Connect the local and global	Local, particular groups and people
Nature of observation	Attempt to study behavior under controlled conditions. Attempt to isolate the casual effect of single variables	Study behavior in more than one context or condition	Study behavior in natural environments. Study the context in which behavior occurs. Study multiple factors as they operate together in natural settings
Nature of reality	Objective (different observers agree on what is observed)	Commonsense realism and pragmatic view of world	Subjective, personal, and socially constructed
Form of data collected	Collect quantitative data based on precise measurement using structured and validated data collection instruments	Multiple forms	Collect qualitative data such as in-depth interviews, participant observation, field notes, and open-ended questions. The researcher is the primary data collection instrument
Nature of data	Variables	Mixture of variables, words, and images	Words, images, categories
Data analysis	Identify statistical relationships	Quantitative and qualitative combination	Search for patterns, themes, and holistic features
Results	Generalizable findings providing representation of objective outsider viewpoint	Provision of insider and outsider viewpoints	Particularistic findings providing representation of insider viewpoints. Present multiple perspectives
Form of final report	Statistical report (e.g., with correlations, comparisons of means, and reporting of statistical significance of findings)	Mixture of numbers and narrative	Narrative report with contextual description and direct quotations from research participants

Table 1: An overview and comparison to the three general approaches to educational research (adapted from Johnson & Christensen, 2008, p. 34, used with permission)

According to Johnson and Christensen (2008) there are five major types of qualitative research approaches: ethnography, case study research, grounded theory, historical research and phenomenology. All these approaches have their distinct characteristics and roots. Johnson and Christensen (2008, pp. 48-50) categorise the five approaches as follow [with examples adapted to the context of engineering]:

> • Ethnography – is the form of qualitative research that focuses on describing the culture of a group of people. Note that a culture is the shared attitudes, values, norms, practices, language, and material things of a group of people. [An example of ethnography could be for the researcher to go and live in an African community and study the culture and how the people in the community deal with engineering problems.]
>
> • Case study research – is a form of qualitative research that is focused on providing a detailed account of one or more cases. [E.g. a researcher] might study a classroom that was given a new curriculum for technology use.
>
> • Grounded theory – is a qualitative approach for generating and developing a theory from data that the researcher collects. [For example, the researcher might collect data from students that have dropped out of engineering education and develop a theory to explain how and why this phenomenon occurs, ultimately developing a theory of student drop-out.]
>
> • Historical research – research about events that occurred in the past. [For example, the researcher might study teaching practices used in engineering schools in the nineteenth century.]

- Phenomenology – a form of qualitative research in which the researcher attempts to understand how one or more individuals experience a phenomenon. [For example, the researcher might interview 20 engineers and ask them to describe their experiences of getting their first job.]

A sixth important area of research not mentioned by Johnson and Christensen is phenomenography, which has its roots in phenomenology but differs in some important ways, such as the focus on a collective rather than an individual experience as discussed below.

According, to Booth (2002) it is important to consider how knowledge is characterised when one discusses learning and teaching for understanding. The two dominant schools of thought on this can be summed up as the rationalist and the empiricist schools. According to Booth (2002), the rationalist school locates "knowledge primarily in the brain or head, with rational thought processes as the means of producing knowledge", while the empiricist school sees "objects in the world as the prime source of knowledge, which humans can never comprehend but can come to terms through experience of the world" (p. 1). Booth further comments that the cognitivist programme of psychology of the present times, where the computer is a metaphor for human cognition, is a clear representation of the rationalist school, while the empiricist school can be seen in the behaviourist movement which dominated education in the middle of the last century. In the former's extreme form, the context of learning is basically ignored as irrelevant in favour of models that describe learning and memory; while in the other's extreme form, the mind is ignored as irrelevant in favour of the correct behavioural responses to given stimulus. The approach guiding this current research project—phenomenography—takes neither of these stances but builds on both and sees knowledge as being a relation between a person and an object (Marton & Booth, 1997). This is expanded on in the next section.

Phenomenography

According to Adawi and Linder (2005) the pedagogical value of phenomenographic research lies in its potential to improve teaching and learning by taking the learner's perspective and focusing on the essential variation in ways that key concepts, principles and phenomena may be thought about.

What is phenomenography? Marton and Booth put it like this (1997): "At the root of phenomenography lies an interest in describing the phenomena in the world as others see them, and in revealing and describing the variation therein" (p. 111). Etymologically, the word phenomenography is derived from the Greek words *phainemenon* and *graphien*, which mean appearance and description, respectively. Phenomenography is thus about the description of things as they appear to people (Adawi & Linder, 2005). The initial development of phenomenography was carried out by a Swedish research group lead by Ference Marton in the early 1970s. Since then many more educational researchers have contributed to the development of phenomenography (e.g., Booth, 2004; Bowden & Green, 2005; Bowden & Marton, 2004; Bowden & Walsh, 2000; Prosser & Trigwell, 1999) and today the field is quite diverse with significant variation between leading phenomenographers.

In phenomenography a fundamental distinction is made between two perspectives—the first- and second-order perspectives (Adawi & Linder, 2005). From a first-order perspective phenomena are described such as they are seen or experienced by experts. This is the perspective taken by, for example, a physicist or an archaeologist. From a second-order perspective the ways phenomena are seen or experienced by others are described. This is the perspective taken in phenomenography (Adawi & Linder, 2005).

According to Marton and Booth (1997): "The basic principle of phenomenography is that whatever phenomenon we encounter, it is experienced in a limited number of qualitatively different ways" (p. 122). These different experiences or conceptions are neither psychological nor physical. They are not located in the subject or in the world, but between these two, i.e. phenomenography takes a nondualist position. Freire (1970) takes a similar position: "World and human beings do not exist apart from each other, they exist in constant interaction" (chapter 1). Descriptions of experiences are descriptions of the internal relationship between persons and phenomena. They say nothing of a phenomenon's true nature but how it is experienced by humans. There is neither a complete, final description nor an unlimited number of descriptions of a phenomenon. This is tied to the nature of awareness. According to Marton and Booth (1997) awareness has two important qualities. The first is that it is not possible to be aware of everything at the same time in the same way. If it this was possible then there would be no variation in experiences. The other is that people are aware of everything at the same time although not in the same way. Thus, "the different ways of experiencing a phenomenon reflect different combinations of the aspects that we are focally aware of at a particular time" (Marton & Booth, 1997, p. 126). If the number of ways of experiencing a phenomenon were infinite then people would live in different worlds, being unable to communicate with each other. Since this is not the case the number of ways of experiencing a phenomenon must be finite (Marton & Booth, 1997). Communication between humans is an act of co-creation or negotiation of meaning.

Marton and Booth (1997) develop these ideas further by suggesting that an experience has a *structural* and a *referential* (or meaning) aspect, which they define in the following way:

> To elaborate first on what we mean by structural aspect, we need to point out that to experiencing something in a particular way, not only do we have to discern it from its context ... but we also have to discern its parts, the way they relate to each other, and the way they relate to the whole. ... The structural aspect of a way of experiencing something is thus twofold: discernment of the

> whole from the context on the one hand and discernment of the parts and their relationships within the whole on the other. Moreover, intimately intertwined with the structural aspect of the experience is the referential aspect, the meaning. (p. 87)

They then differentiate the structural aspect further by suggesting "[t]hat which surrounds the phenomenon experienced, including its contours, we call its *external horizon* [italics added]. The parts and their relationships, together with the contours of the phenomenon, we call its *internal horizon* [italics added]" (p. 87).

Another side of this is that the ways of experiencing a phenomenon are not only connected to individuals, but they exist on a collective level as well. In fact, in phenomenography the collective level is what is the most important, since the aim is to find the various ways in which people in a certain group experience a certain phenomenon and it is possible that individuals only express some of the different ways or fragments of ways of experiencing that phenomenon (Marton & Booth, 1997). Thus, "the description we reach is a description of variation, a description on the collective level, and in that sense individual voices are not heard" (Marton & Booth, 1997, p. 114).

As stated earlier, phenomenography focuses on this variation. To elaborate: "The objective of a study is to reveal the variation, captured in qualitatively distinct categories, of ways of experiencing the phenomenon in question, regardless of whether the differences are differences between individuals or within individuals" (Marton & Booth, 1997, p. 124). Thus, the aim of a phenomenographic study is to construct a system of *categories of description* of a certain phenomenon. This system is called the *outcome space*. To be more precise: "The outcome space is the complex of categories of description comprising distinct groupings of aspects of the phenomenon and the relationship between them" (Marton & Booth, 1997, p. 124). Since a phenomenographic study always derives its descriptions from a small number of people chosen from a particular population—the system of categories can never be claimed to be a definitive system. However, the goal is that the categories should be complete in the sense that nothing in the collective experience as manifested in the population under investigation is left unspoken (Marton & Booth, 1997).

There are three criteria for the quality of a set of categories (Marton & Booth, 1997). The first is that the individual categories should each stand in a clear relation to the phenomenon under investigation so that each category tells something distinct about a particular way of experiencing the phenomenon. The second is that the categories have to stand in a logical relationship with one another, a relationship that is frequently hierarchical. The hierarchical structure is based on an increasing complexity in the ways of experiencing the phenomenon. However, Green (2005) emphasises that categories of description are not necessary always hierarchical. The third and last criterion is the usage of as few categories as is feasible and reasonable for capturing the critical variation in the data. In the end the description obtained "is a stripped description in which the structure and essential meaning of the differing ways of experiencing the phenomenon are retained, while the specific flavors, the scents, and the colors of the world of the individuals have been abandoned" (Marton & Booth, 1997, p. 114).

Since phenomenography focuses on the collective experiences of various phenomena the research material—e.g., interview transcripts—is treated as one source instead of various sources—the *pool of meaning* (Marton & Booth, 1997). When data—e.g., relevant quotes—is drawn to create the categories of description there is no need to reflect upon which source it came from. Nevertheless, Åkerlind (2005) points out that not all phenomenographers use this approach, but rather consider whole transcripts or large chunks of transcripts at a time, e.g., Bowden (2000) prefers to deal with whole transcripts to avoid de-contextualisation of utterances. However, regardless of approach it is important to note that not only categories of description, but even their fragments, are distributed across individuals. Therefore, according to Marton and Booth (1997) the data at the collective level are particularly robust compared with the data relating to individuals. In other words data is drawn from individuals and are combined to categories of description on the collective level. Even if it might be difficult or impossible from the data or the whole study to conclude in which ways individual subjects experience a phenomenon, the ways in which idealised individuals do so can be abstracted due to the overlap of the material seen at the collective level. This also relates to the usual practice of selecting a theoretical sample of subjects to cover the group according to a predetermined plan to maximise the variation in critical respects (Marton & Booth, 1997)—in this study the aim for gender balance and a blend of different personalities among the interviewees to the extent it was possible.

When it comes to applying the results of a phenomenographic study Marton and Booth (1997) put it like this:

> [A] description of a way of experiencing might apply in some sense across a group, or, there again, might apply to some aspect of an individual. To the extent that the group represents the variation of individuals in a wider population (or is a theoretical sample of that population), the categories of description can also be said to apply to that wider population. (p. 124)

However, as already has been stated the outcome space is connected to the test group and thus there might be limitations of how much the categories of description can be generalised. Nevertheless, as has been repeatedly stated phenomenography focuses on variation and according to Marton and Booth (1997): “Even if the empirical statements about individuals or groups may not be generalizable, the variation itself might very well turn out to be so” (p. 128). For example, in a study of the ways in which a group of Hungarian and a group of Swedish secondary school students understood a short story by Franz Kafka, it was found that the variation was identical between the two groups. Thus the variation found in phenomenographic study might be generalisable across different cultures (Marton & Booth, 1997).

When using a phenomenographic approach, researchers try to put brackets around their own conceptions of the phenomenon of study to minimise the effect of their own biases. However, since phenomenography is an interpretive research method it is impossible to completely remove the researcher's biases and choices, especially in the quite artificial construction of a set of categories of description. One way of reducing researcher biases is to work in iterations with one or several colleagues and construct the categories together. Even when a researcher is doing the analysis alone iteration is key to a robust outcome space.

Classical examples of phenomenographic inquiry are investigations of conceptions of learning where students with higher conceptions see learning "as seeing something in a different way" as well as "changing as a person" (Marton, Dall'Alba & Beaty, 1993) or even "changing the person and the world" (Trigwell, Prosser, Marton, & Runesson, 2002). Students with lower conceptions see learning as "increasing one's knowledge," "memorizing and reproducing," "applying," and "understanding" (Marton et al., 1993).

To summarise, a phenomenographic study aims to find the variation in ways in which a phenomenon is experienced by a certain group of people and describe this as a limited number of qualitatively different conceptions. These conceptions vary around key critical aspects and an understanding of these and the way they are structured can then help to create learning experiences such that the students experience this variation.

Example of an outcome space

To give an example of an outcome space of a phenomenographic study, the categories of description from a previous study (Kabo, 2006) I have conducted are summarised here. The aim of this previous study was to identify and describe the qualitative different ways in which engineering physics students conceptualised technology. Technology was discussed in interviews with ten students and six categories were found in the data (the interviews). These categories could be arranged in a hierarchical system, presented in Figure 3. The first three categories form one group, where the focus is on technology as *products*. The last three categories form another group, where the focus is on technology as *processes*. The higher categories represent a greater and more complex understanding of technology than the lower ones.

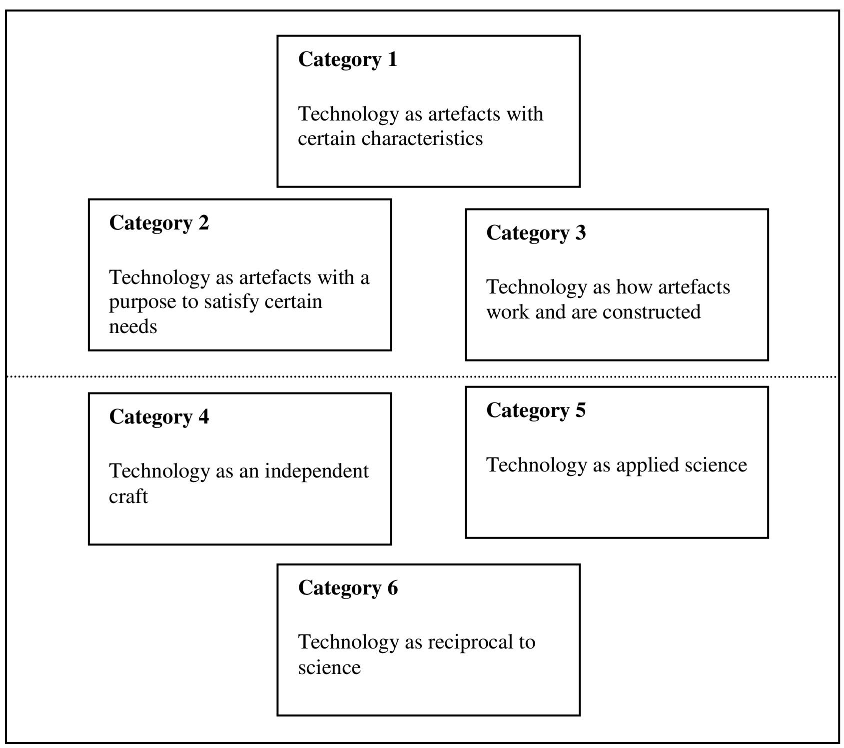

Figure 3: A phenomenographic outcome space with six categories of description arranged into a hierarchical system (Kabo, 2006, p. 21)

The transition from one category to another is marked by a change in one or more of central characteristics. A person can be present in more than one category—which often was the case with the interviewees. Different tendencies could also be observed in the results—these are summarised in Figure 4. A quite obvious trend is the transition from a very simple conception of technology in Category 1 to a more complex conception in Category 6. Another is the shift from technology as something static and concrete to something dynamic and abstract. Yet another is the change in humans' roles in relation to technology—from passive observers to active creators and developers. Here it can be noted that the role as developer is quite open—depending on the category different names might be used: craftsman, scientist or engineer. At the same time there is a shift in focus from products to the actual development process.

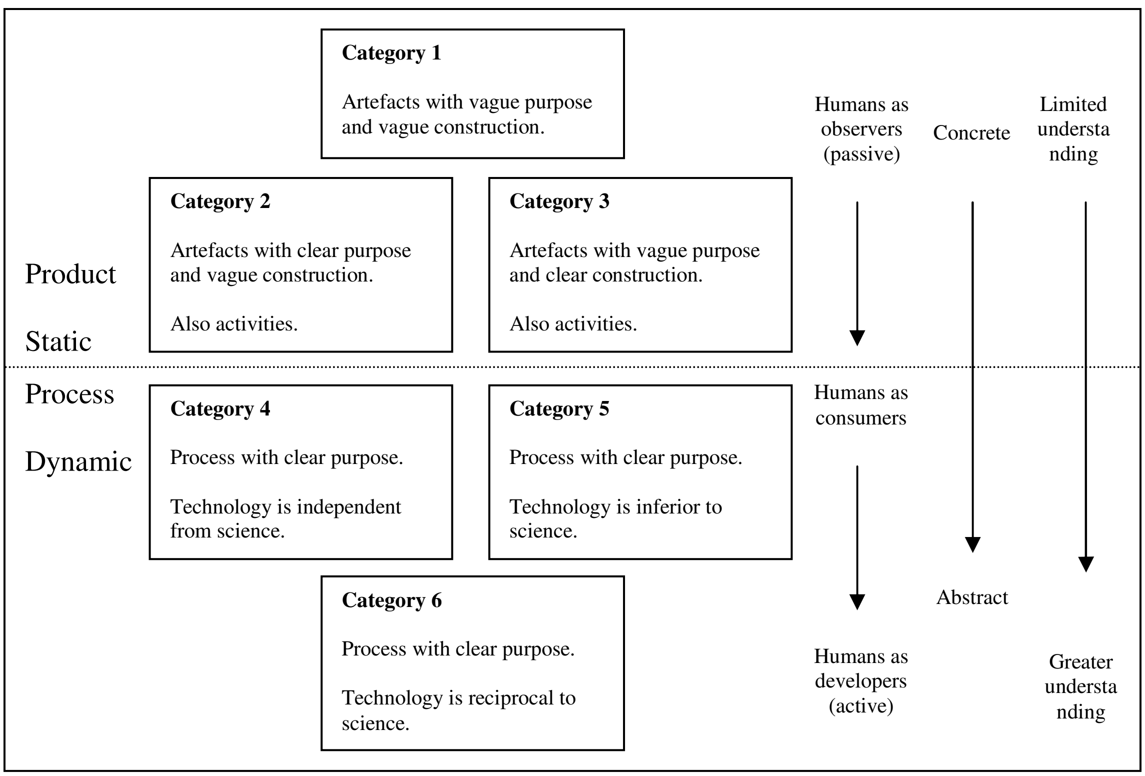

Figure 4: Overview of different trends and central characteristics in a phenomenographic outcome space (Kabo, 2006, p. 42)

Variation theory

A key aspect of phenomenography described above is variation. Variation theory has emerged out of the phenomenographic tradition over the last ten years (Bowden & Marton, 2004; Marton & Booth, 1997; Marton & Tsui, 2004). According to Bernhard, Carstensen, and Holmberg (2007): "Central to this theory is that we learn through the experience of difference, rather than the recognition of similarity'' (p. 4). Booth (2004) illustrates this well in the following fictional example of understanding the concept of the colour red:

> If an alien from another planetary system landed on Earth and showed themselves to have a physical sense of colour but no concept of colour, how would you teach them to distinguish red from the other colours? One way, the obvious maybe, is to show them red objects and tell them that they are red. This would lead to a connection between the objects of that colour and the concept of red. But would they be able to distinguish red from the other colours? Not unless the difference had been grasped, and that would mean the teaching effort would have to bring red objects into the alien's awareness at the same time as objects of other colour and the distinction brought to focal awareness. Now suppose that the objects to hand are children's building bricks in a variety of colours, including red. Which would be the more effective – to show red only in terms of one size and shape in relation to blue and green and pink bricks of different shapes and sizes? Wouldn't that be to risk that particular shape and size being associated with redness, thereby losing generality? No, surely, to show different shapes and different sizes while maintaining redness as a common feature is the way to bring about a general awareness of red as a colour. To continue with flowers of different colours and

> form would add to the effect. It is *variation* and *invariance* that are the key points here. The concept of red is brought into focal awareness by exposure to a deliberate *variation* in size, shape and type of object in relation to objects of other colours, while the property of redness in maintained *invariant*. (p. 14)

Central concepts in variation theory are *discernment*, *awareness* and *simultaneity* and *variation*. "In order to see something is a certain way, a person must discern certain features of that thing. We should also be clear about the difference between *discerning* and *being told*" (Marton, Runesson, & Tsui, 2004, p. 10). Discerning is to actively experiencing something which is crucial for learning rather than passively being told. The nature of *awareness* was discussed in the previous section on phenomenography, but in short it "is the totality of a person's experiences of the world, at each point in time. It is all that is present on every occasion" (Marton et al., 2004, p. 18). There are two versions of *simultaneity*—"*diachronic* (experiencing instances that we have encountered at different points in time, *at the same time*) and *synchronic* (experiencing different co-existing aspects of the same thing at the same time)" (Bernhard et al., 2007, p. 4). All phenomena are defined by their critical features, e.g., for a pen some of these are colour, shape, size and type, and these features are subject to *variation*. Marton et al. (2004) identify certain patterns of *variation*:

> *Contrast*. [In] order to experience something, a person must experience something else to compare it with. In order to understand what "three" is, for instance, a person must experience something that is not three: "two" or "four," for example. This illustrates how a value (three, for instance) is experienced within a certain dimension of variation, which corresponds to an aspect (numeriosity or "manyness").

> *Generalization*. In order to fully understand what "three" is, we must also experience varying appearances of "three," for example three apples, three monkeys, three toy cars, three books, and so on.
>
> *Separation*. In order to experience a certain aspect of something, and in order to separate this aspect from other aspects, it must vary while other aspects remain invariant.
>
> *Fusion*. If there are several critical aspects that the learner has to take into consideration at the same time, they must all be experienced simultaneously. (p. 16)

The relationship between *discernment*, *awareness* and *simultaneity* and *variation* can be described in the following way:

> The kinds of capabilities we focus on are those that empower learners to deal with situations in powerful ways, that is, to simultaneously … focus on features critical for achieving a certain aim. However, we can only experience simultaneously that which we discern; we can only discern what we experience to vary; and we can only experience variation if we have experienced different instances previously and are holding them in our awareness simultaneously. … So the three (or rather four) key concepts of the theory are intimately linked, each of them being a function of another. (Marton et al., 2004, p. 20)

The following closing remark clarifies the role of variation in relation to learning:

> We are not arguing for variation in general, and we are not saying the more variation there is, the better the possibilities to learn. What we believe is that variation enables learners to experience the features that are critical for a particular learning as well as the development of certain capabilities. In other words, these features must be experienced as dimensions of variation. (Marton et al., 2004, p. 15)

Threshold concept theory

Threshold concept theory (TCT) (Meyer & Land, 2003) represents a relatively recent and growing area in educational research. The assumption made within the TCT model of learning is that there are in most, perhaps all, (disciplinary) knowledge domains, certain concepts that serve as gateways to further progress as learners and deeper levels of knowledge. The idea is that part of the process of grasping a threshold concept is that learners change the way they see the subject or part thereof and potentially themselves (in relation to the subject). The changes in thinking and seeing are what open up previously inaccessible knowledge areas. However, the process of grasping these concepts might prove troublesome for some learners, leaving them stuck and unable to move forward (possibly for some time).

The term “concept” does not necessarily have to be interpreted in the narrow sense of a scientific concept. For example, social justice is not a concept in the same sense as gravity or complex numbers are concepts in engineering. Social justice represents a way of seeing the world. However, the metaphor of the threshold is still useful for describing engineering students’ attempts to approach social justice. Meyer and Land (2003) raise the notion that there might exist ways of thinking or seeing that will have the same transformative effect as their proposed concepts.

Part of grasping a threshold concept seems to involve the learner moving closer to how people think within a discipline. In other words threshold concepts are likely to be key points in a gradual shift from a novice mindset to an expert mindset in relation to a subject or discipline. This leads to the notion of "thinking like an engineer" or "thinking like an economist" etc. However, the position maintained in this dissertation is that social justice (as related to engineering) cannot be seen in this light since it both originates outside the discipline and challenges the status quo of the disciplinary community.

Threshold concepts 101: Suggested characteristics

According to Meyer and Land (2006a, p. xv) the idea of threshold concepts was first introduced in discussions on learning outcomes as a way of distinguishing core learning outcomes that represent seeing things in a new way from those that do not. Meyer and Land suggest that threshold concepts are something special within what many university teachers would describe as core concepts. Meyer and Land (2003) identify five qualities that seem to characterise threshold concepts. According to them threshold concepts are likely to be: *transformative, irreversible, integrative, bounded* (define boundaries), and *troublesome*. This is not a definitive list of required characteristics and all threshold concepts will not necessarily display all five qualities.

The most distinguishing characteristic of threshold concepts is their *transformative* qualities, since this is what sets them apart from core concepts. Meyer and Land (2003) suggest that understanding a threshold concept has the potential to drastically shift how a person perceives a subject or part thereof. According to Cousin (2006a) this conceptual shift is coupled with an ontological shift. "We are what we know. New understandings are assimilated into our biography, becoming part of who we are, how we see and how we feel" (p. 4). Meyer and Land (2003) propose that in certain cases—such as grasping a specific politico-philosophical insight—the new understanding will result in a transformation of personal identity, which often involves a shift in values, feeling, or attitude. Thus, while the comprehension of a threshold concept always involves a reposition of the self in relation to the subject, it does not necessarily involve a reconstruction of the learner's subjectivity.

The perspective shift caused by the grasping of a threshold concept is likely to be *irreversible*. Meyer and Land (2003) mean that once a threshold concept is understood it is unlikely to be forgotten and will be difficult to unlearn. For some concepts the new transformed perspective will open the eyes of learners for things that they have not noticed before and once something has become seen it cannot go back to being unseen. Cousin (2006b) gives the comprehension of the concept of otherness by people of mixed race as an example of this. Meyer and Land (2003) argue that this irreversibleness can make it difficult for a subject expert who passed through a threshold long ago to understand the problems facing those who struggle to cross it—this is likely to be the case for many teachers and their students (Cousin, 2006b). Even though a threshold might be unlikely to be forgotten or unlearnt, a learner's conception of it can still change. According to Cousin (2006b) a concept might later be modified or rejected, but the learner will act from an internalised understanding of it.

A third characteristic of threshold concepts is that they are *integrative*; they bring related concepts and phenomena together in ways previously unknown to a learner and expose the hidden interrelatedness between these (Meyer & Land, 2003). An example of this might be that grasping a feminist perspective is likely to help a learner bring together and relate previously isolated notions and experiences, such as the wage-divide between men and women and the traditional division of work in the home. Davies (2006) argues that threshold concepts due to their integrative qualities help to provide coherence to a subject.

A fourth characteristic of threshold concepts is that they often help to *define the boundaries* of a subject area since they clarify the scope of a subject community (Davies, 2006).

Meyer and Land (2003) mean that any conceptual space will have a finite limit with thresholds into other conceptual areas. Part of mastering the threshold concepts that distinguish a chosen subject area is the learner to move from being an outsider to the field of study to belonging to it (Eckerdal et al., 2006), in other words moving from a novice mindset toward an expert mindset in relation to the subject.

The last characteristic of threshold concepts is that they are potentially (but not always) *troublesome*. Even though a threshold concept is not always troublesome this still seems to be something that is very central to them. Both epistemological and ontological obstacles contribute to the troublesomeness of threshold concepts. Perkins (1999, 2006) and Meyer and Land (2003) discuss what they call troublesome knowledge and link it to threshold concepts. Perkins has defined troublesome knowledge as something: "which appears counterintuitive, alien (emanating from another culture or discourse), or incoherent (discrete aspects are unproblematic but there is no organising principle)" (quoted in Meyer & Land 2003, pp. 5-6). Mayer and Land (2003) and Perkins (2006) suggest that there are five kinds of troublesome knowledge: *ritual* (e.g., memorising specific recipes for problem solving in physics or engineering), *inert* (e.g., passive vocabulary—it is something known but it cannot be reflected upon or used actively), *conceptually difficult* (e.g., knowledge that defies the logic of common-sense-views and experiences of everyday life), *foreign* or *alien* (knowledge that comes from a perspective that is in conflict with one's own, e.g., "presentism" in history—to look at historical events through present knowledge and values—or potentially value systems that are part of different cultures), and *tacit knowledge* (knowledge connected to things that are taken for granted within a knowledge domain without ever being brought up to discussion or reflection). A consequence of this is that an expert understanding of a threshold concept is likely to clash with a common sense or intuitive understanding of the same concept. According to Cousin (2006a) this can hinder a learner in internalising the concept in question, and the process of reversing an intuitive understanding can be troublesome since it often involves an uncomfortable, emotional repositioning. Cousin goes on to argue that the difficulty of fully grasping a threshold concept is not necessary only inherent in the concept itself but is also related to the learner and the social context. Meyer and Land (2006b) drawing on work of Elizabeth Ellsworth (1989), suggest that students who cannot identify with the image of "the typical student" (young, white, male, middles-class, heterosexual and so on) might find learning troublesome due to an unconscious anxiety about its transformative effects, which in turn are tied to the common ways of thinking in our society. This is likely to be reinforced in the case of threshold concepts, both due to their transformative qualities and their connection to expert ways of thinking within subjects or disciplines. Davies (2006) brings up another troublesome consequence of threshold concepts and their connection to expert ways of thinking, suggesting that once a threshold concept is mastered it becomes taken for granted by practitioners in a discipline and hence is rarely made explicit (similar to an expert's difficulty of looking back across a threshold long crossed). This is problematic due to the fact that threshold concepts are proposed to play a critical role in student learning (Meyer & Land, 2003), and therefore they need to be made explicit to the students or other non-experts. Despite their proposed troublesomeness, Entwistle (in Bradbeer, 2006) cautions against seeing threshold knowledge (concepts) simply as something that is hard to grasp.

Liminality, liminal space, and variation

Due to the transformative qualities of threshold concepts the process of internalising a threshold concept can be seen as a transition from one relatively stable state of knowing or being to another. Drawing on the work of Carl Jung as well as ethnographic research, Meyer and Land (2005, 2006b) use the terms *liminality* or *liminal space* to describe this transition. Liminality is a "space" of uncertainty and flux that different learners will navigate in different ways and with differing degrees of success; some might, for example, get stuck unable to move forward, while others will oscillate back and forth between different states of knowing, being, and seeing. Meyer and Land (2005) suggest that in a Western context adolescence can be seen as a liminal state, a place where the youth is no longer a child, but not yet an adult. Meyer and Land argue that even though temporary regression to an earlier state often happens, there is no full going back. Land, Cousin, Meyer, and Davis (2006) acknowledge that learners might have to take a recursive approach to their attempts to grasp a threshold concept. Another strategy some learners appear to deploy in their attempts to navigate a liminal space is mimicry of the desired understanding or way of thinking. Cousin (2006b) points out that while mimicry can be a first step towards understanding, it can also be a form of ritualised learning. As an example related to understanding otherness, Cousin (2006b) observes: "that students can 'do sexism' just as they can 'do the Ancient Romans'" (p. 140), i.e., while these students might have learnt the definition of sexism they have not truly internalised the concept into their way of seeing the world.

To better capture variation present in how students navigate a liminal space, Meyer, Land and Davies (2008) introduce different states of liminality. They discuss *pre-liminal*, *liminal, post-liminal,* and *sub-liminal* variation, that is, variation in the ways in which students see the concept come into focus, pass through the threshold, come out the other side, and their predisposition for knowledge building in the discipline.

Additionally, the introduction of variation in different states of liminality serves to link threshold concept theory to variation theory frameworks, such as the one that have emerged from the phenomenographic research tradition. Although variation might be useful both for understanding differences in student learning and in helping students grasp difficult concepts, central to TCT is that there are certain interpretations and conceptualisations that are more preferable than others and these are the transformed perspectives of those that have internalised the threshold concepts in question. According to Meyer et al. (2008) there needs to be a theoretical rationale that justifies particular conceptions of phenomena to learners in a discipline, and this rationale is grounded in the ways of thinking and practicing characteristic for the discipline.

Communities of practice and disciplinary ways of thinking

A reoccurring theme in literature on threshold concept is that they usually seem to be linked to certain disciplinary ways of thinking and practicing (e.g., Meyer & Land, 2003, 2005; Land *et al.*, 2006; Davis, 2006). More precisely, the idea of getting students to start to think as the practitioners of their chosen discipline seems to be a central part of the threshold concept framework. In other words, part of becoming a member of a disciplinary community involves acquiring a mindset characteristic of the discipline in question. According to McCune and Hounsell (2005):

> The ETL team coined the phrase "ways of thinking and practising" (WTP) in a subject area, to describe the richness, depth and breadth of what students might learn through engagement with a given subject area in a specific context. This might include, for example, coming to terms with particular understandings, forms of discourse, values or ways of acting which are regarded as central to graduate-level mastery of a discipline or subject area. … WTP can potentially encompass anything that students learn which helps them to develop a sense of what it might mean to be part of a particular disciplinary community, whether or not they intend to join a given community in the future, for example, by pursuing a particular profession. (p. 257)

Davies (2006) suggests that "ways of thinking in a subject necessarily entail particular ways of practicing" (p. 70). McCune and Hounsell (2005) observe in their study of WTPs in biological science that "a sea-change in the biosciences students' ways of thinking about what was known and understood within the field appeared to be tightly interwoven with their practising of the subject" (p. 284). Davies (2006) then emphasises the link between joining a community and the influence of a shared perspective within the discipline on the learner in question. According to him:

> The act of learning is an act of identity formation. In coming to see the world in a particular way learners associate themselves with a community of people who share that way of thinking and practicing and through this they position themselves in relation to others inside and outside of that community. (p. 71)

Land et al. (2006) emphasise that from their point of view it is crucial that learners develop a specific disciplinary mindset, i.e., in history "[w]e will wish our students not only to understand 'how historians think,' but to begin to 'think like a historian'" (p. 199). Later Meyer and Land (2010) pose the question: "How many times does a student have to interrogate historical texts before an ontological horizon appears – the dawning of the realisation of thinking like an historian?" (p. 67). Their answer involves treating threshold concepts as the "jewels in the curriculum" and focus education around these.

Opportunity cost in Economics is a "popular" threshold concept example (e.g., Meyer & Land, 2003, 2005; Shanahan & Meyer, 2006) and can be used to illustrate some aspects of the threshold concept framework. Opportunity cost is the value placed on the most valuable rejected alternative to a made choice. It emphasises that choices always comes at a cost. When something is chosen other things are rejected or not prioritised. "Thus, if 'accepted' by the individual student as a valid way of interpreting the world, it fundamentally changes their way of thinking about their own choices, as well as serving as a tool to interpret the choices made by others" (Meyer & Land, 2003, p. 3). However, the question is how many students manage to internalise the full meaning of opportunity cost when they first encounter it since:

> When the dust settles, most students leave the introductory course never having fully grasped the essence of microeconomics. Thus the opportunity cost concept, so utterly central to our understanding of what it means to think like an economist, is but one among hundreds of other concepts that go by in a blur. (Frank cited in Meyer & Land, 2003, p. 10)

Davies and Mangan (2007), who have studied potential threshold concepts in economics, do not see threshold concepts in a discipline as a set of isolated magic concepts (that presumably unlock a fuller understanding), but rather as a web of related concepts that partly reflects the historical development of thinking within a subject. They go on to say:

> We can illustrate the importance of the web of concepts by looking at the acquisition of the threshold concept of "opportunity cost." The analytical power of this concept is only realised when it is used in conjunction with other economic ideas. For example, an economist's explanation of the level of profits in a perfectly competitive industry, and an economist's argument about the desirability of free trade, would necessarily involve opportunity cost. However, opportunity cost is not sufficient for an economist's perspective on either of these issues. … However, developing a way of thinking that embodies either one of these theories transforms the use to which a learner may put their understanding of opportunity cost, and may also transform their

> perception of the relationship between opportunity cost and other economic ideas that they have acquired. (pp. 722-723)

The web of concepts and the observation that many students of Economics fail to grasp concepts such as opportunity cost may be linked to some extent. Land et al. (2006) speculate that:

> Students who do not think of themselves as “learners of Economics” are likely to face particular difficulties in grasping concepts that bind together aspects of a subject that may seem quite disparate to a novice. This problem arises because the acquisition of such concepts (e.g., opportunity cost, price and value, equilibrium) is intrinsic to grasping the ways in which economists “think” and practice. (p. 195)

In a latter publication, Meyer and Land (2010) expand on this further:

> [W]hat emerged in this context was what was perceived by tutors as a “lack of commitment” on the part of students who characterised themselves as “being there to study Economics” but did not see themselves as “students of Economics.” In this instance the necessary preliminal ontological shift required for the programme was not deemed to have taken place. (p. 75)

The key term here is preliminal ontological shift which Meyer and Land (2010) describe as follows:

> [T]he preliminal ontological shift creates a receptive predisposition *beyond* tacit understanding of the “underlying game” which prepares the student for threshold concept engagement. (pp. 74-75)

In other words, the essence of what Meyer and Land are saying is that students' attitude to and/or conceptualisation of the profession for which their programmes are preparing them will influence how easy or difficult it will be for these learners to internalise the threshold concepts of the discipline or acquire the ways of thinking and practicing of the discipline. Meyer and Land (2010) contrast the experiences of the economics students mentioned above with that of medical students, who usually are more distinct in their ambition to become physicians. Meyer and Land suggest that medical education often is very successful in initiating students into the disciplinary community of physicians. The following description offers a good illustration of the socialisation process the medical students undergo through their education:

> [T]he carefully choreographed sequences of human behaviour involving (for the student) a transformative rite of passage in beginning to *look* like a doctor (white coat, stethoscope, neat grooming), *talk* like a doctor (what we refer to as the discursive aspect; elaborated use of language, increasing use of medical terminology and language), *act* like a doctor (professional demeanour, clinical detachment, bedside manner, as variously exhibited on ward rounds, in eliciting a clinical history, performing a physical examination, presenting clinical cases), and *think* like a doctor (hypothetico-deductive and probabilistic reasoning, reaching a differential diagnosis). (Meyer and Land, 2010, p. 74)

This description resonates with the previous citation of Davies (2006) that learning is an act of identity formation—the medical students form a new identity of being a doctor. Also, it suggests that an educational environment that helps students develop and reinforce a positive attitude to and conception of their chosen profession will facilitate for the students to grasp the threshold concepts of the discipline. Overall, it seems difficult to separate the discussion of threshold concepts, ways of thinking and practicing, and disciplinary communities since they are dependent on each other and almost have a reciprocal relationship. Threshold concepts help develop WTPs and WTPs facilitate the grasping of threshold concepts. Meyer et al. (2008, p.67) highlight these relations but also suggest that if there are contrasting schools of thought within a discipline this might have consequences for some learners trying to internalise certain concepts:

> It is in the nature of disciplinary thought, or the possibility of identifying a community of scholars, that the threshold concepts which are developed by those scholars stand in a distinct relationship to each other (Davies and Mangan, 2007). They may complement each other, forming a web of inter-related threshold concepts, operating together to provide an episteme ("way of knowing"), or "underlying game" (Perkins, 2006). Alternatively, in distinct subsets, they may define contrasting schools of thought within a disciplinary community, In either case, developing an understanding of a previously unfamiliar threshold concept involves further transformation in understanding of threshold concepts with which the learner is already familiar. An individual may, for example, move from one school of thought to another within a discipline, re-working their previous understanding of the discipline.

Rowbottom (2007) has critiqued the theory of threshold concept (Meyer and Land, 2003, 2005) for not clearly defining what a concept entails and exactly what characteristics make a "threshold concept" unique compared to other concepts. In addition, he expresses scepticism toward the idea that learning certain concepts is enough to develop certain abilities. He also questions if transformative qualities are something unique to threshold concepts—in his mind all concepts are transformative to some extent. Much of this criticism seems to come from a positivist point of view. Ray Land (personal communication, June 17, 2008), who has a postmodernist background, points out that in his mind threshold concepts are not limited to a narrow, positivist definition of scientific concepts, but are a fluid term that cover a range of meanings. Entwistle (2005) expands this by comparing learning experiences of students in history and economics.

> Although individual concepts did not seem to have the transformative property found in economics, this changed way of thinking did seem to act as a threshold for students' academic progression in history. …There were also some ideas that appeared to have the transformative effect of threshold concepts, even though the concepts themselves are less clear-cut than in economics. … In some subject areas, great stress is laid on learning outcomes that involve the acquisition of technical concepts. Many such concepts can be readily acquired from the explanations and examples provided but, as we have seen, others create much more difficulty and yet are crucial in opening up the subject. These have been termed "threshold concepts," and this notion can be extended to describe threshold ways of thinking found, for example, in history. Either of these forms of threshold can markedly change the intellectual landscape seen by the student. (p. 77-80)

On a similar note, Meyer and Land (2003) suggest that in disciplines where there is a lesser degree of consensus on what constitutes a body of knowledge (e.g., history compared to economics), threshold concepts are less likely to be identified. Nevertheless, they echo Entwistle's argument by proposing that there can still be certain ways of thinking and practicing in a discipline that serve crucial threshold functions that lead to a transformed understanding.

According to Cousin (2006b) Cultural Studies (which is anti-disciplinary in its nature) is an example of a "community of practice" where it might prove difficult to create a system of stable threshold concepts due to the sprawling and internally disputed nature of this area of shared practice. Even so, Cousin suggests that the concept of otherness serves a threshold function for people entering into this area of practice. So when one looks beyond disciplinary differences, what stands out as the unifying theme in these discussions is the *metaphor of the threshold*—regardless whether it is connected to particular concepts, webs of concepts, or ways of thinking and practicing. In addition, a detail that has permeated most of the perspectives and points brought up in this section so far, is the importance social relationships have for acquiring the transformed understandings passing through a threshold is supposed to bring. Rowbottom (2007) seems to miss this aspect of the threshold concept framework. In addition, his argument that all concepts are transformative to some extent may hold some weight, but it seems that most of the time the transformations proponents of the threshold concept framework envision must be seen in relation to the disciplinary community in question. First and foremost, threshold transformations relate to how learners understand and view their chosen discipline. However, according to Cousin (2006a) this conceptual shift is coupled with an ontological shift. "We are what we know. New understandings are assimilated into our biography, becoming part of who we are, how we see and how we feel" (p. 4). Meyer and Land (2003) suggest that the magnitude of this ontological shift will vary from situation to situation, concept to concept, and person to person. They argue that going through a threshold experience (especially internalising a specific threshold concept) always involves a reposition of the self in relation to the subject, but it does not necessarily involve a major reconstruction of the learner's subjectivity. While the threshold metaphor potentially can be useful for illuminating various types of transformations that involve resistance, difficulty, or troublesomeness, it is usually (at least in the main branch of threshold theory) linked to the ways of thinking and practicing of a disciplinary community.

McCormick (2008) introduces the acquisition (AM) and the participation (PM) metaphors of learning and uses them as a lens to look at how Meyer and Land (2003) present threshold concepts. According to McCormick, the AM view of learning "sees knowledge as an object (e.g., a concept) that has to be acquired by students … and the more understanding they have, the more their frameworks will replicate that of an expert in the subject" (pp. 51-52). In other words, from this perspective the key thing for learners is to "know more." The PM view of learning, in contrast to the AM view, "takes a more social view of knowledge construction … knowledge is not an object but is knowing how to participate in [a] community's practices. One important implication of this is that learning is 'becoming', 'creating an identity'" (p. 52). In other words from this perspective the key thing for learners is to "know differently." McCormick then concludes that Meyer and Land's presentation of threshold concepts takes on a mix of the two metaphors, with an AM approach when discussing disciplines where concepts are quite definite such as mathematics and the sciences and a PM approach when discussing learning in areas such as music, but most of the time the two metaphors overlap. McCormick uses the PM metaphor to raise some points about threshold concepts. One point is the service function some subjects play in other subjects or disciplines, e.g., mathematics in engineering education, and how this potentially leads to students developing different identities depending on whether or not the subject is their primary, e.g., being a mathematician versus an engineer using mathematics. Consequently, insights about a threshold in a subject from one disciplinary community might not be directly transferable to another community using the same subject. Another of McCormick's points is that classrooms are more likely to reflect the community of practice of "learning" the subject in question than the actual community of practice of the practitioners of the subject. This observation may have significance since one of the main underpinnings of the threshold concepts framework is the idea that education serves as an entrance to specific disciplinary communities.

Hegemonic ways of thinking and practicing?

In the concluding section of their seminal paper on threshold concepts, Meyer and Land (2003) acknowledge the following concern:

> A further significant issue is that threshold concepts might be interpreted as part of a "totalising" or colonizing view of the curriculum. Such a view would point to the effects of power relations within curricula with threshold concepts serving to provide a measure, and exert a "normalizing" function in the Foucaldian sense (Foucault, 1979, 1980). *Whose* threshold concepts then becomes a salient question. These are non-trivial concerns and merit further consideration.

At the time of writing, they have yet to follow up on this theme in their main series of papers *Threshold concepts and troublesome knowledge* (Meyer & Land, 2003, 2005, 2010; Meyer et al., 2008; Land, Cousin, Meyer, & Davis, 2005). On a related note, Savin-Baden (2008) explores the notion of liminality that Meyer and Land (2005) uses to frame students struggle to pass over a threshold—navigating the liminal space successfully or get stuck in limbo. She observes that:

> [M]ovements away from liminal spaces tend to be celebrated differently and are often seen as being eccentric, for example choosing not to graduate following a PhD but instead to make a quilt with friends, or carrying out a peace ceremony at home to celebrate the resolution of a difficult and troublesome conflict. Such ritual or symbolic expression are therefore often hidden or have been moved into hidden spaces. As a result, these rituals are

> often marginal and seen as subversive of social control. Thus, it might be that liminality could be seen as ultimately hegemonic because it is used to maintain rituals and the status quo—or might it be that it is the ritualistic practices that bring about liminality which in themselves are necessarily hegemonic. (pp. 84-85)

She continues:

> It might be that threshold concepts themselves are becoming hegemonic in higher education. … "[E]mbedding" threshold concepts in curricula in an epistemic may be problematic. This is because to embed concepts might not only result in disregarding the importance of learner identities but also may be seen as creating or affirming a dominant narrative and as a means of ritualising disciplinary practice. Thus it might not be possible to "become" an engineer, lawyer or economist unless the student has passed over a number of given knowledge thresholds. (p. 85)

Savin-Baden's concern that threshold concepts can become hegemonic is acknowledged by Cousin (2008), who by drawing on the work of McCune and Hounsell (2005) observes that "the risk is of representing hegemonic WTPs as *the* WTPs" (p. 263) and that this risk also is present when identifying threshold concepts. According to Cousin, this is why threshold concepts are theorised as "provisional, contestable and culturally situated" (p. 263). For example, "a Keynesian economist and a Marxist one may propose different threshold concepts for the economics they respectively teach because they have quite different views about what is central to their subject" (Cousin, 2008, p. 263). Indeed, teachers' "epistemological stance" or subscribed "school of thought" will most likely be inducted onto their students in addition to the subject they teach. While this line of argument might support a non-hegemonic stance on the nature of threshold concepts, from a Freirian (1970) perspective it does problematise power relations in the local context of the classroom. In addition, the research reported on in this dissertation indicate that dominant disciplinary ways of thinking can indeed be hegemonic and that this in turn can create thresholds for a whole discipline against alternative ways of thinking. Since threshold concepts are envisioned to be linked to the WTPs of a disciplinary community this is an important point, and thus threshold concept researchers need to pay attention to the impact on a discipline of "common sense" WTPs. Otherwise, there is a risk that the threshold concept theory might help to create conformist communities of practice which might in turn lead to less dynamic and inspiring learning environments which most likely will have a negative impact on students' learning. This would then go against the spirit of the threshold concepts movement since its mission partly is to enhance student learning.

New ways of thinking

Meyer and Land (2006b, p. 25) relate the new ways of seeing that Einstein introduced into his community of practice to the potential creation of a threshold:

> Einstein, in this instance, was not traversing a threshold concept already in existence, *he was creating the threshold*, and perhaps to a certain extent creating his own liminality. It is feasible that this form of liminality may be quite common to the process of conducting fundamental research, which creates new thresholds rather than extending or elaborating the domains (boundedness) of existing ones. Indeed it might be argued all creative movements in forward research share a similar quality of liminality as that which appears within the Einstein story.

In addition to being conceptually difficult, general relativity represents a very different way of conceptualising space and time than the Newtonian way most physics students are used to. From this example it can be speculated that the introduction of new ways of seeing into a disciplinary community can create new thresholds. Einstein was still working within the discipline of physics, but came up with a new way of seeing.

Flanagan (2007) speculates that new thresholds can arise in cross-disciplinary contexts and observes that computer science and non-computer science students, e.g., electrical engineers, negotiate liminal spaces or cross thresholds related to learning to program in different ways. He suggests that a possible factor behind this is that non-computer science students do not "benefit from being in an environment that facilities their embracing of the ethos of the computer science community and from the reinforcement of a wider computing curriculum" (p. 2). However, non-computer science students who successfully cross the thresholds "move rapidly into a mode of discussing their work in a manner [similar to that of computer science] and can be observed volubly attempting to take a partner over the threshold" (p. 4).

Flanagan (2007) observes that "[a]n increase in *interdisciplinarity* is becoming a common theme across the [engineering] disciplines, and is likely to involve greater enculturation issues than those presented by present day disciplinary overlaps" (p. 6). Nanotechnology is proving to be one such area. Flanagan speculates that in an interdisciplinary context threshold concepts of one discipline might migrate into another discipline and for members of this other discipline it might be even more difficult to successfully navigate the liminal space since they will be less familiar with the associated disciplinary ways of thinking. It is suggested that quantum mechanics, which in recent times has started to filter into other disciplines, is an example of this, since it "is so strange that for many students, especially those outside a physics department, it may be one of the disciplines that is an overwhelming threshold conception" (p. 6).

Closing thoughts on threshold concepts

A theoretical understanding of threshold concepts is still under development. However, Cousin (2008) acknowledges that many of the ideas around threshold concepts have been theorised before and ideas from previous work may be drawn upon to understand the new work arising from studies of threshold concepts. Threshold concepts bring focus to the notion that epistemology and ontology—the studies of knowing and being—are always intertwined and need to be kept together. The ambition of Meyer and Land (2003, 2005, 2010) as well as others, seems to be to create an overreaching theoretical framework that can be used in many different disciplines; but at the same time, they emphasise that the way in which concepts are understood is likely to vary from discipline to discipline and even from concept to concept. Potential threshold concepts have been put forward in a range of disciplines: for example, *complex numbers* in pure mathematics (Meyer & Land, 2003), *opportunity cost* in economics (Meyer & Land, 2003), *pain* in medical science (Meyer & Land, 2005), *signification* in literary and cultural studies (Meyer & Land, 2003), and *otherness* in cultural studies (Cousin, 2006b). These concepts are very different in nature, but share the potential to be both transformative and troublesome to learners in respective disciplines or knowledge areas. According to Cousin (2008) research on threshold concepts represents a shift away from "how to best teach something" to "what is best to teach?" The ambition is to avoid a stuffed curriculum. She also reports that threshold concepts have shown to be a useful devise to make teachers talk about teaching and learning in their discipline. To conclude, the idea of threshold concepts represents an attempt to understand differences in student learning and whether there are some concepts that are more important than others in the development of disciplinary thinking. The framework might prove more suitable for some disciplines than others. Savin-Baden (2008) suggests that "[T]hreshold concepts are not ‘concepts’ per se, they are troublesome spaces that emerge in the life world of the learner that are connected to their biographies and identities as learners” (p. 86).

Summary of Important Themes

In this chapter a range of perspectives and conceptual frameworks were explored in order to situate and give context to the research project reported on in this dissertation. Engineering and engineering education were discussed in light of a growing awareness of the importance to acknowledge the social impact of engineering and that engineers might need an expanded skill set (e.g., enhanced critical thinking and problem definition) to participate in a constructive manner in addressing the pressing issues of poverty and environmental sustainability humanity faces. However, adapting new ways of seeing (e.g., seeing engineering through a social justice lens) might be nontrivial due to the “common sense” perpetuated by existing thought collectives. There are educational traditions, e.g., critical pedagogy, that are aimed at helping students develop the ability to see beyond this “common sense,” but as Mezirow (2000) observes “[s]ubjective reframing commonly involves an intensive and difficult emotional struggle as old perspectives become challenged and transformed” (p. 23). The emerging educational research area of threshold concepts offers two ideas—the threshold metaphor and liminal space—useful for framing this kind of transformative and troublesome learning experience. In this dissertation the interest is not in the more usual threshold “concepts” but rather threshold “ways of thinking or seeing.” While ideas from threshold concept theory are useful as framing devices, a research approach is needed in order to study student learning experiences. Phenomenography offers a framework for developing a suitable approach. In the next chapter these frameworks are brought together and operationalised into the methodology and method used to guide the inquiry of the research project.

Chapter 3

Research Approach and Scope of the Project

Suggesting social justice as a threshold for engineering is one thing, investigating the same suggestion another. For such an investigation to be carried out, the different frameworks overviewed in the preceding chapter need to be brought together and operationalised into a methodology and a method to guide the inquiry. In this chapter the genesis, hypothesis, methodology, method and progression of the research project reported on in this dissertation are discussed.

Genesis and Hypothesis of the Research Project

The genesis of the research project reported on in this dissertation occurred in 2006 when Caroline Baillie taught the course *Engineering and Social Justice: Critical theories of technical practices* for the first time. Baillie noted that students taking the course appeared to move into what Meyer and Land (2005) refer to as a *liminal space*, which is a "space" of uncertainty, flux, and transition between two different states of knowing, being, or seeing. Some students were able to apply a critical social justice lens in discussions and assignments, i.e., they were able to pass though the liminal space and were able to reach the desired course outcomes. Other students had difficulty changing how they thought about engineering and technology and adopting alternative views and can thus be said to have become stuck in the liminal space. Yet others (the majority) tried different ways of approaching adopting social justice as a critical lens and can be said to have been moving back and forth in the liminal space uncertain of how to pass through. Clearly, for most students in the class it was not trivial to start thinking about engineering in terms of social justice. Drawing on Meyer and Land (2003), Baillie hypothesised that for engineers, both practising and students, adopting a socially just perspective to their practice and profession could be seen as a threshold that needs to be crossed and that this transition might prove both transformative and troublesome. This hypothesis is reflected in the following statement from an engineering student who attended the course in 2008:

> **QS13:** This course has had a huge effect on my way of thinking. Big time! … It really messed with my head. Sometimes I was scared to go to class because I didn't want to think about stuff … I feel now that I look at things from a different perspective or CAN … I feel I'm going to think more socially about making certain decisions. But I think it could have an impact on my success within a company ... (SIGH) this course... [**I:** A bit scary...?] Yeah most definitively!

The title of this dissertation is therefore: *Seeing Through the Lens of Social Justice: a Threshold for Engineering*. The aim of the research project was to understand what can be done to help students navigate this proposed liminal space and to better understand how courses such as the one mentioned above shift students' perceptions of engineering and social justice.

Research questions

The following three questions guided the inquiry:

- How can students be encouraged to adopt a social justice lens toward their practice and profession?
- What are the ways in which students vary in their approach to taking a socially just perspective to engineering?
- What is the variation between courses that take slightly different approaches to a similar goal of encouraging students to develop their critical thinking abilities?

Methodology

This study used an adapted phenomenographic framework combining elements from phenomenography and threshold concept theory, both of which have focus on variation as an important component. This allows for studying and describing the range of experiences of a group of (engineering) students approaching adopting social justice as a lens for looking at engineering practice. Below the relevance of each framework for the study reported on in this dissertation are discussed as well as how they were combined to a merged methodological framework.

Threshold concepts as a framework for analysis

As described in the previous chapter, internalising the threshold concepts of a discipline is often seen as part of the process of becoming a full member of the disciplinary community and at the same time the preferred ways of thinking and practicing of the discipline are acquired. This leads to the notion of “thinking like an engineer” or “thinking like an economist” etc. Social justice (as related to engineering) cannot be seen in this light since it both originates outside the discipline and challenges the status quo of the disciplinary community. However, rather than discarding the threshold framework, this study will help to expand and develop this aspect of the framework. There are for example similarities to Meyer and Land’s (2006b) story about Einstein and the creation of a threshold when new ways of seeing are introduced into a community of practice. However, this area of the framework remains largely unexplored and most work to this date has focused on finding the threshold concepts of various disciplines (e.g., Boustedt et al., 2006; Davies & Mangan, 2007; Flanagan, 2007; Shanahan & Meyer, 2006; Lucas & Mladenovic, 2006).

Baillie and Rose (2004) point out that "it is important to realise that for something to be known, it must fit within the relevant community's paradigm or thought collective" (p. 20). The term "thought collective" originates with Fleck (1979) and was discussed in the previous chapter. Fleck suggests that thought collectives give rise to distinct ways of thinking or what he designates thought styles and that these have consequences.

> It constrains the individual by determining "what can be thought in no other way." Whole eras will then be ruled by this thought constraint. Heretics who do not share this collective mode and are rated as criminals by the collective will be burned at the stake until a different mode creates a different thought style and different valuation. (p. 99)

And when two different thought styles collide:

> The alien way of thought seems like mysticism. The questions it rejects will often be regarded as the most important ones, its problems as often unimportant or meaningless trivialities. (p. 109)

Wenger (1998) discusses, on a related note, potential consequences of belonging to a community of practice:

> The understanding inherent in a shared practice is not necessarily one that gives members broad access to the histories or relations with other practices that shape their own practice. Through engagement, competence can become so transparent, logically ingrained, and socially efficacious that it becomes insular: nothing else, no other viewpoint, can even register, let alone create a disturbance or a discontinuity that would spur the history of practice onward.

> In this way, a community of practice can become an obstacle to learning by entrapping us in its very power to sustain our identity. (p. 175)

What both Fleck and Wenger are saying is that the established ways of thinking within a community or group can serve as barriers toward new knowledge building, i.e., potentially *create thresholds*. As an example of this, Baillie and Johnson (2008), by studying the attitudes of first year engineering students in a professional skills class, found that the students experienced "professionalism" as a threshold. The view of engineering presented in the class clashed with some students' perceptions, which were more aligned with applying science to solve problems in a classroom than the communication and collaboration required in real world engineering. These students could be said to form a thought collective based on their high school experience and this worked as a barrier when presented with a new view of engineering. After some time in an engineering programme, students will most likely become part of a new thought collective represented by engineering education. In line with the hypothesis presented above, we have, in a previous publication (Kabo & Baillie, 2010), suggested then that seeing through the lens of social justice might prove to be a barrier for engineering students who are in this thought collective.

In the same publication (Kabo & Baillie, 2010), we also presented empirical support for our suggestion of social justice as a barrier. Interview data on this theme was gathered as part of the study reported on in the next chapter. Students were asked about what they felt hindered their learning or what they perceived as barriers to their understanding of social justice. As shown below, the students experienced several things, both at a collective and an individual level, as blocks or barriers toward adapting social justice as a lens for their practice.

> **QS7:** [In class] everyone kept bringing up efficiency. ... and I just thought why is efficiency so important and my personal kind of conclusion was that

it’s because we have to make a profit and be, you know everyone is taking commerce classes or business classes that are talking about the economy. ... So I feel like that concept being so prevalent is why the environmental crisis seems inevitable to me is that, unless we stop growing, I mean we just can’t continue to grow and this idea of growth just doesn’t seem to get questioned. ... I mean I know people who are very environmentally conscious and they do their best and they’re really pro uh, they’re very positively favoured towards environmental causes, but the idea of not growing still seems just so hard to imagine to them and I think those two things conflict.

QS9: Especially in engineering where you’re always told these are the courses you need to take if you want to be a professional engineer, here’s your core curriculum and this is the way you’re thinking. It’s almost like a little cookies cutter, you just go along and you make little engineers and then you throw them out into the real world. But yeah, once you’re the little gingerbread cookie cutter guy out there you have to realise there are so many different viewpoints.

QS9: After the [traditional Canadian engineering] ceremony I brought the feminism aspect to say well why is it so male dominated and some people, yeah, some people flat out said well that’s the way it’s always been.

QS5: I can see that this kind of engineering [pro bono] is not going to happen without government sanction. You know liabilities ... you cannot do anything without being sued nowadays. So the fact that doctors can do pro bono work and are covered by the government, lawyers can do pro bono work and are

> covered by the government, it should be extended to goodwill for any sort of profession, but engineers should actually be covered.

> **QS10:** I've really noticed that it's really hard to break down some of those taken for granted assumptions that people have and that often you really, revert back into your old thinking patterns even though you're challenging those kinds of things.

Some students felt that their previous experiences of the engineering culture and engineering education strongly emphasised money, profit making and efficiency as well as being conformist and traditional. The students felt that all of these served as obstacles for shifting engineering more toward social justice as well as providing personal challenges. In addition, approaching social justice was perceived as having the potential of involving sacrifice, risks, doubts and discomfort. Some interviewees also felt it was difficult to move beyond the things they took for granted. It can be argued that most of these perceived barriers can be tied to the culture of the engineering profession and consequently these barriers most likely arise from the current dominant ways of thinking and practicing in engineering. These observations provide support to the merit of exploring the proposed hypothesis of the social justice threshold for engineering.

Due to their transformative qualities, the processes of internalising a threshold concept can be seen as a transition from one relatively stable state of knowing or being to another. Meyer and Land (2005) use the terms *liminality* or *liminal space* to describe this transition. 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. The idea is useful to illustrate the variation in how different students progress towards adopting social justice as a perspective to problem solving. The liminal space in which students hover for several weeks, not knowing whether or if they will eventually pass through the portal into new territories, is explored in detail in this study. In addition, the discussion of the liminal space is expanded through the use of Meyer et al.'s (2008) idea of pre-liminal, liminal and post-liminal variation, that is, variation in the ways in which students see the concept come into focus, pass through the threshold and come out the other side. In a previous publication (Kabo & Baillie, 2009a), in order to better capture the fluid nature of a liminal space, we re-framed this somewhat by introducing the notion of a continuous liminal spectrum that goes from a pre-liminal state to a post-liminal state. A visualisation of this can be seen in Figure 5.

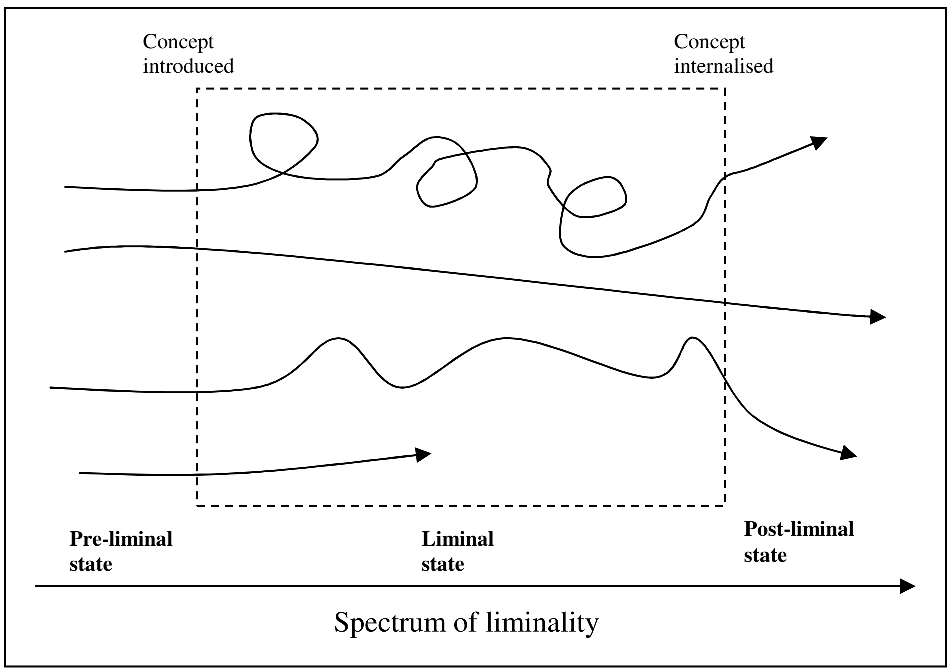

Figure 5: How different learners might navigate through a liminal space

For the current study, threshold concept theory provides two conceptual constructs: First, it provides the metaphor for framing social justice as a threshold for engineering. Second and more importantly, it provides the idea of liminality or liminal space which is useful for framing the (learning) experiences of (engineering) students attempting to approach and adopt social justice as a critical lens for their practice and profession.

Phenomenography as a framework for analysis

According to Marton and Booth (1997): “The basic principle of phenomenography is that whatever phenomenon we encounter, it is experienced in a limited number of qualitatively different ways” (p. 122). In this study, social justice is the “phenomenon” of interest. Despite the “mutability and multiplicity” (Riley, 2008c, p. 1) of social justice, the idea is, based on the arguments discussed in the phenomenography section in the preceding chapter, that within a given population (here the students of each course studied) there will exist, on the collective level, a limited range of different conceptions of social justice, which differ from each other through variation in critical aspects. The aim of a phenomenographic study is to reveal this variation and then construct an *outcome space* in the form of a system of *categories of description* of the phenomenon in question, here social justice.

For the current study, phenomenography provides an approach for mapping variation in critical aspects of how, for example, social justice is understood, on the collective level, among a group of (engineering) students. Åkerlind (2005) explains the strength and rationale of this approach:

> This focus on critical aspects allows structural relationships to be highlighted in a way that would not be possible if the analysis focused on every nuance of meaning. At one level, each individual’s experience of a phenomenon is unique. But a simple descriptive collection of such unique ways of experiencing would be of little power or usefulness in guiding educational change. By contrast, the phenomenographic researcher tries to make the

variation in experience meaningful, by searching for structure and distinguishing aspects of variation that appear critical to distinguishing qualitatively different ways of experiencing the same phenomenon from aspects that do not. The aim is to describe variation in experience in a way that is useful and meaningful, providing insight into what would be required for individuals to move from less powerful to more powerful ways of understanding a phenomenon. (p. 73)

In addition, as a research approach phenomenography can be argued to offer an edge that makes it suitable for the exploration of the ways engineering students understand social justice as they attempt to adopt it as a critical lens. Marton and Booth (1997) observe that:

> Phenomenography, when applied to the phenomena dealt with in established disciplines, thus focuses on the meanings on which knowledge about the different phenomena rest, especially in relation to the meanings that those phenomena may have for the learner entering respective fields of knowledge. The question of the taken-for-granted ways of experiencing phenomena is largely ignored within the research effort in fields that are stable; they are generally characterized by contemporaneous self-evident ways of seeing. Sometimes, however, the very question of how certain phenomena are experienced may turn out to be rather central to the field itself. (p. 121)

Marton and Booth' words suggest that phenomenography offers a way to unearth the meanings underlying these taken-for-granted ways of seeing which allows for exploration of understandings beyond them.

A combined framework

Phenomenography and threshold concept theory (TCT) both provide important aspects for framing the research discussed in this dissertation. Threshold concept theory, through the idea of liminal space, provides a way to frame the students learning experiences as they attempt to approach adopting social justice as a lens. Furthermore, the idea of different liminal states, which we (Kabo & Baillie, 2009a) have recast as a liminal spectrum, provides a basic structure for the outcome space of the study. Phenomenography, on the other hand, provides the approach to map the variation in conceptions of, for example, social justice present among a group of (engineering) students as well as a rationale for how to organise the data, i.e., identify a "phenomenon's" critical aspects. Both frameworks are united through the focus on variation in how students navigate the liminal space associated with social justice.

The outcome space of this study differs from those of traditional phenomenographic studies. However, as Dall'Alba (2000) observes:

> Even with those aspects of the research results that are not presented in the established format for categories of description ... the underlying principle of describing ways of thinking about and understanding a phenomenon or aspect of the world and presenting these findings as the main outcomes of the research is maintained. (p. 98)

In this study the categories of description correspond to different positions along the spectrum of liminality as students attempt to pass through the threshold. The idea is that when learners move along the spectrum they acquire increasingly complex conceptions or ways of seeing. A visual representation can be found in Figure 6. However, this is not to suggest that the process of crossing a threshold or navigating a liminal space, or even more generally the process of learning, is linear. The mapping of the liminal space of social justice is in line both with the phenomenographic idea that students can hold several conceptions of the same phenomenon simultaneously and with the idea of oscillation between different liminal states suggested by threshold concept theory.

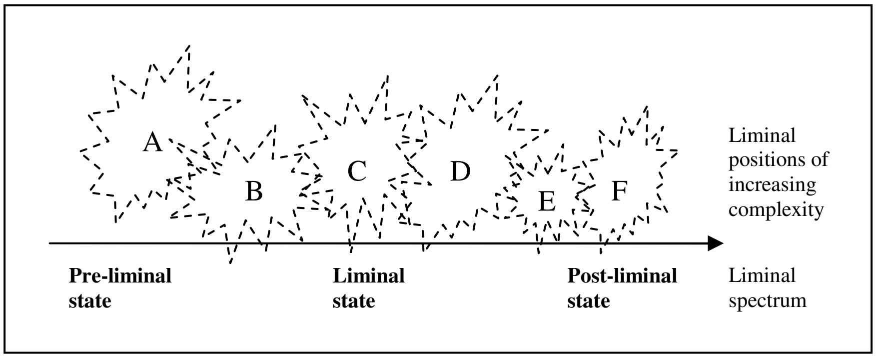

Figure 6: A conceptual model of a liminal outcome space: a product of the combined frameworks

The proposed conceptual model, which combines aspects of phenomenography and threshold concept theory, allows for studying and describing the range of experiences of a group of (engineering) students approaching adopting social justice as a lens for looking at engineering practice. Their collective journeys across the threshold toward more complex understandings of social justice can be mapped in the form of a liminal outcome space.

Another example of a research project that draws on and combines the two frameworks is an ongoing study funded by the Australian Learning and Teaching Council. The researchers of this project intend to:

1. Identify Threshold Concepts relevant to first-year in their discipline;
2. Conduct action research on variation in student understanding of these concepts;
3. Co-design learning activities informed by this variation and the Variation Theory of learning;

4. Implement the design and assess learning outcomes; and
5. Re-design learning activities based on this theory and evidence. (Australian Learning and Teaching Council, n.d.)

These aims parallel those of the research project reported on in this dissertation and add merit to the decision to combine the two frameworks by showing that this type of approach can be useful in other contexts beyond the one explored in this dissertation. The third point highlights how the outcomes of the study, as per the variation theory of learning (Marton & Tsui, 2004), have a pedagogical value. First, a threshold is identified; then, variation in different liminal states is studied; and then the identified variation is used as a pedagogical vehicle to help students develop their conceptions of the phenomenon in question and by doing so cross the threshold. An example of how this can be done with social justice in engineering is given in Chapter 7. Here the outcome of an earlier study (reported on in Chapter 4) was used in the classroom to help the students develop their understanding of social justice, i.e., it was the variation around the conceptions at different places on the liminal space that allowed students to move through the threshold. The proposed conceptual model (Figure 6) can be used by instructors to frame this type of learning activities.

In a wider academic context, the combination of threshold concept theory (TCT) and phenomenographic variation theory can be seen in the following way: Threshold concept theory provides a way of identifying and framing potentially transformative and troublesome areas of a curriculum, phenomenography provides a way to study and identify critical variation in students' conceptions of the phenomena in these areas, and variation theory provides a pedagogical way to make use of the identified variation to help students progress in their learning.

Method

In this research project data was collected through a mixture of qualitative research methods: interviews, focus groups, content analysis of student assignments and in-class-observation. Interviews were the primary data collection method, with student assignments and in-class-observation constituting secondary data sources. Focus groups were used in one of the three studies as a vehicle to bring in additional student perspectives on the group project component of the course; this data was pooled with the interview data. The exact numbers and specific details of each study will be discussed in the next three chapters; here the focus is on the general approach used and common elements between each study with some specific examples to provide illustration of certain points.

The ambition was to capture as many possible ways of thinking about social justice in each of the courses studied. Rather than trying to interview as many students as possible, the aim was to get a diverse group of interviewees to capture as much variation as possible within the context of learning. The number of interviewees was kept to around 10-15 (or fewer due to class size) for each project to keep the amount of data manageable. Kvale (1996) comments that the number of interviews needed becomes known first when the answer sought has been reached. However, Kvale also advises against too many interviews since the research material becomes difficult to handle except with statistical methods. However, despite the ambition of selecting a diverse group of interviewees, in some case external constraints put a limit on how diverse this group could be. For example, at the second research site (the course *Sustainable Design Politics and Culture*) the standard ethics guidelines stipulated that all students were to be given the same opportunity to participate and thus initially the interviewees were self-selected. However, after I had been present in the class for a few weeks it was possible to approach and invite specific students to balance (from my perception) the group of interviewees. Generally in each study, interviewees were chosen based on gender, academic discipline (if known), and how they participated in the class (i.e., their apparent classroom personality). However, actual class composition also put restrictions on how diverse the group of interviewees could be. For example, in the study of the course *Engineering and Social Justice* all engineers who participated in interviews were male and all social scientists were female due to the class composition. Also, the technique of basing interviewee selection on observed class participation tended to favour the more outgoing and active students of a class. Notwithstanding, I tried to balance this somewhat by approaching more passive students later in each study when I was more familiar with the class and students in question.

The rationale for using interviews as the main source of data, rather than, for example, questionnaires, was that interviews have the potential to allow more exhaustive answers. Also, with interviews the researcher has more control when collecting the empirical data and is able to follow up interesting themes that emerge. The interviews were semi-structured to allow the conversation to take its course without too much steering from myself, the interviewer. The interviews were audiotaped and transcribed verbatim.

In the cases where additional data sources were available the outcome of the inquiry could to some extent be triangulated from these various sources. Triangulation is one approach of several where three or more different kinds of data—here interviews, student assignments and in-class-observation—are collected on the same issue and used to shed light on each other (Somekh & Lewin, 2005). This results in a more rigorously constructed outcome. However, in each of the three studies the outcome spaces of how students thought about social justice were drawn exclusively from the interview transcripts. Class observation and student assignments were used to provide context to each study and to provide input about key pedagogical characteristics of each class (see Chapter 7).

The data gathered was analysed following the principles described in the section on phenomenography. Bowden and Marton (cited in Beeman & Baillie, 2007) explain how interviews are analysed using a phenomenographic approach:

> All interviews were transcribed and the transcripts subjected to rigorous phenomenographic analysis. This involved one member of the research team taking responsibility for reading all transcripts related to a given question and devising a draft set of categories of description drawn from the transcripts ... an iterative process was used to produce final descriptions. (p. 3)

When relevant quotes were found these were highlighted and collected to form a pool of meaning. The selected quotes were then read through several times and the data was organised according to the various themes that emerged. The process of organising the data was carried out in a series of steps which served to reduce and focus the amount of data used. This was done slightly differently between the first study (conceptions of social justice in the *Engineering and Social Justice* course) and latter studies. In the first study, relevant quotes were first highlighted and then (what I considered to be) the essence of each quote was written down on a Post-it™ note. These Post-it™ notes were then grouped according to emerging themes. The corresponding quotes were then organised accordingly. Then a series of iterations of reading, reorganising and reducing the number of quotes followed. In latter studies the Post-it™ step was not used. Instead relevant transcript sections were marked and similar processes of reading, reorganising and reducing followed. In each case the iterative process continued until the themes could be formalised in a system of developed conceptions of social justice spread out over the spectrum of liminality. To increase rigour, the data and the emerging categories of description were continuously discussed with the project supervisor, and to some extent the professor responsible for the course under study. In the case of the latter study of the *Engineering and Social Justice* course (perceptions of engineering) student assignments were treated in a similar manner as the interview transcripts.

Chronicle of the Project

This section is intended to give a brief overview of the progression of the project reported on in this dissertation progressed and to provide insight into the three pilot studies that was carried out. The duration of the project spanned roughly three years from January 2007 to January 2010, with each year more or less corresponding to a distinct phase of the project.

Phase 1

During the first phase, the focus was on mapping out the research area and finding a focus for the research as well as carrying out pilot studies to hone skills needed for the research, such as interviewing, and to try out different approaches to data gathering. Throughout the year three pilot studies were carried out.

- **Pilot 1** – This study was aimed at understanding what students learn from problem solving activities in the "real world," in this case represented by an exercise in which students taking a structural analysis course were required to calculate the deflection for an existing bridge in Kingston by visiting the bridge and taking measurements. Observation of the students and two interviews were carried out, tape recorded and transcribed. These were used to develop an appreciation of interview skills and also to begin to identify the ways in which students express their experiences. Furthermore, the preliminary data analysis facilitated an understanding of learning in terms of variation and the structure of the students' experience.

- **Pilot 2** – In this study, the use of video recording and video recall was explored. Four participants in an introductory physics course aimed at students in the biological and life sciences were filmed in the classroom while solving one chosen problem and then during a follow up interview they were asked to comment on how they went about solving the problem. This was followed by a discussion about the course and the student's learning. The outcome of this study was the decision to not use video in the future since the video component of the interview did not seem to help the recall (Halimaa, 2001) of the broad conceptual themes under study. It is a more useful technique for studying specific behaviour of students in laboratories etc. It was concluded from this study that audio recorded interviews and observation would be adequate as the main data sources and that video was not to be used.
- **Pilot 3** – In this study the potential of concept mapping (Kinchin & Hay, 2000) as a tool used in interviews which attempt to reveal variation in conceptual understanding was explored. Seven students in a solid mechanics course for mechanical engineers were interviewed about a problem dealing with combined loading they had solved during a tutorial. Combined loading was chosen as a focus of the study as the instructor had observed that this was something that some students seemed to struggle with and therefore it had the potential to act as a threshold. As part of the interview the students were asked to draw a concept map. However, based on my experience of trying the technique in practice and after reviewing the concept maps produced I decided that the effort required to properly introduce the interviewees to the technique in order to get meaningful data did not make it worthwhile to pursue any further. Audio recorded interviews and observation were again concluded to be adequate as the main data sources. In addition, this pilot study also indicated the benefit of as researcher embedding oneself

in the context under study over a longer time than just a few class sessions, as I had done in this study, in order to get a better understanding of the context in question.

This project was started with a broad interest in problem solving in engineering education and the emerging threshold concept theory framework. In addition, there was an intention of applying a critical perspective to the inquiry. By the fall of 2007, social justice as a threshold for engineers was chosen as the main focus of the study and by the end of the year the course *Engineering and Social Justice: Critical theories of technological practices* (E&SJ) at Queen's University had been selected as an ideal first research study.

Phase 2

During the second phase, the focus was on collecting data for the study and starting the process of analysis and reporting. The first quarter of 2008 was dedicated to the study of E&SJ as described in Chapter 4. During, the second and third quarters my main focus was on analysing interview transcripts. During this time the courses *Sustainable Design Politics and Culture* (SDPC) at RPI and *Science, Technology, and Ethics* (STE) at Smith College had been identified as suitable candidates for expanding and adding critical variation to the project. In September I relocated to the United States to study these two courses concurrently as described in Chapter 5 and Chapter 6. The fourth quarter was dedicated to these studies.

Phase 3

During the third and last phase, the focus was on finishing up the analysis and reporting the findings. During, the first quarter of 2009 the E&SJ course was revisited for additional study in order to expand the scope of the original study. During, the second and third quarters my main focus was on analysing interview transcripts from SDPC and STE as well as student course assignments from E&SJ. During the fourth quarter all remaining data analysis was concluded and the process of reporting the findings in the form of this dissertation slid into focus.

By the end of January 2010 the project was concluded.

Some Concluding Words

In this chapter the various frameworks presented in the preceding chapter have been brought together and operationalised to into a conceptual model which combines key aspects of phenomenography and threshold concept theory. This conceptual model provides framing and approach for an inquiry into students' navigation of the proposed threshold as well as how the courses under study shift students' perceptions of engineering and social justice. In addition, the genesis and progression of the research project has been described. In the next four chapters the outcomes of the project will be reported.

Chapter 4

Exploration of Engineering and Social Justice in a Classroom

What is it engineers do anyway? Vesilind (2006) frames Florman's (1976) answer to the question in the following way:

> Engineers build things. Their greatest job satisfaction is watching something they conceive, design, and construct, actually perform as intended. Samuel Florman beautifully describes this joy as an "existential pleasure"—existential in that the process of doing something is independent of its end use (Florman 1976). The end use of something does not matter to the engineer, argues Florman, and the engineer has the existential freedom to do good engineering and not be concerned about what the product or facility will eventually be used for, or who uses it. The joy of engineering is to make knowledge useful. (p. 283)

Vesilind does not agree with Florman's somewhat narrow vision for the profession and argues for the emergence of a new kind of engineering—peace engineering—"rooted in the greater ideals and aspirations of engineering as a service to all of humanity" (p. 283). Indeed, Florman's ideal is a poor match for the increasing emphasis put on awareness of the social impact of engineering discussed in Chapter 2. In a similar vein, Williams (2002) comments that while many engineers might identify as problem solvers, engineers cannot solve all of the world's problems by themselves. They need to understand both the limits of their knowledge and abilities and the value of collaboration with other professions and disciplines. Williams and Vesilind are not the only ones expressing concern and critique of the traditional approach to engineering problem solving. Others include Baillie (2006), Baillie and Catalano (2009a, 2009b, 2009c), Bhatia and Smith (2008), Catalano (2006, 2007) Reader (2006), Riley (2008c), and Zoli, Bhatia, Davidson, and Rusch (2008). Riley and Baillie, in particular, have attempted to address these issues directly with students in order to facilitate the development of engineers in the future who have a more holistic view of problem definition and problem solving. However, moving students from their "common sense" (Gramsci, 1971) position of the role of engineering, to entertain and assimilate new lenses for their future profession, have been found to be troublesome (Baillie, 2002). For students to overcome the perceived "thresholds" a case can be made that students first need to develop the ability to critically analyse and deconstruct "common sense" views of engineering. This chapter reports on the study of a course that aimed to focus this process of critical analysis and deconstruction through a critical social justice lens. The course fits into a wider tradition of "critical pedagogy" or education centred around social justice that dates back to Freire (1970). Bell (2007) captures the essence of this tradition:

> The goal of social justice education is to enable people to develop the critical analytical tools necessary to understand oppression and their own socialization within oppressive systems, and to develop a sense of agency and capacity to interrupt and change oppressive patterns and behaviors in themselves and in the institutions and communities of which they are part. (p. 2)

The kind of critical reflection encouraged by this educational tradition is, according to Mezirow (2000), key to any significant shifts of the frames of reference people hold. However, Mezirow points out that "[s]ubjective reframing commonly involves an intensive and difficult emotional struggle as old perspectives become challenged and transformed" (p. 23). In the work presented here, the term liminality (Meyer & Land, 2005) is used to frame the process whereby students' conceptions of engineering and social justice are challenged and potentially transformed. As the course under study is interdisciplinary we have investigated (Kabo & Baillie, 2009b) how it challenged the view of engineers and engineering held within respective thought collectives (Fleck, 1979). The main aspect that distinguishes the course reported on in this chapter from the ones in the two subsequent chapters is the strong explicit focus on engineering and social justice and the use of social justice as a critical lens.

This chapter is broken down in the following way: First, the context, thematic and practical aspects of the course as well as the research approach used are described. Then, the findings are presented in the form of a liminal outcome space for social justice and emerging perception shifts of engineering among the engineering and social science students in the class. The chapter is concluded with a summary and some reflections.

The Course "Engineering and Social Justice" and Queen's University

The course *Engineering and Social Justice: Critical theories of technological practice* was developed and first taught at Queen's University, Canada, by Richard Day (Sociology) and Caroline Baillie (Engineering) in 2006. Queen's University was founded in 1841 and is today a midsized university with a full range of programmes from engineering to the humanities. It is considered one of Canada's leading universities. The genesis of the course *Engineering and Social Justice* was Baillie's idea that it should be possible to analyse engineering in the same way as has been done with science and technology (see Baillie & Catalano, 2009, pp. 13-27, for examples).

Baillie asked the following questions: What is engineered? Who is it engineered for? What happens inside engineering organisations? Is it equitable? Does engineering have to contribute to capitalism to the extent it does, even at times driving the extreme forms of capitalism that are notable in some multinational organisations?

Guided by these questions, Baillie and Day designed a course in which engineering and social science students come together to develop critical perspectives toward technology in general and engineering practice in particular. The course is a second level elective open to engineering and social science students of years 2, 3 and 4. As the reputation of the course developed, the percentage of social science students (to almost 50/50) and the numbers of students taking the class increased (to a cap of 30).

The what

The two main approaches of the course were the deconstruction of the "common sense" of current engineering practices and the creation of alternative practices which are non-oppressive, non-capitalist, and ecologically sustainable. These themes were explored through weekly readings and other media such as film clips and guest speakers. As well as exploring basic definitions of social justice and engineering, the course began by introducing the students to key concepts related to the social construction of technology (society shapes technology) and technological determinism (technology shapes society). The dominant engineering paradigm of technological and capitalist rationality was explored and critiqued from its rise during the Industrial Revolution to its current phase of neoliberal globalisation. Neoliberalism, according to Riley (2008c), is "capitalism that places ultimate faith in private property, free markets, and free trade, privatizing industries and lifting any government protections on trade, the environment, labour, and social welfare" (p. 7). Globalisation in this context refers to expanding these ideas beyond the Western national state to a global market. Towards the latter part of the course, alternative paradigms were explored through a series of lenses.

The how

The class met once a week for a three hour seminar. Both instructors were present at all times. This enabled the students to see difference in ways of thinking in action that made them feel more able to question terminology or concepts that they did not understand. Each class was split into two sessions usually focusing on different topics and readings with one of the instructors taking the lead for respective sections. Often the instructor leading would give a short introduction to the topic at hand and then open up the floor for class discussion. Alternatively, a film clip or a guest speaker would introduce the topic. The discussions were the main dynamic of the classroom through which the week's topics were explored, but at times this was interspersed with small group exercises. In addition to participating in the discussions the students engaged with the course themes by writing two critical response essays and carrying out community based group projects (in which they were to critically examine elements of engineering practice). These essays were of crucial importance to the development of the students' thinking. Individual and detailed feedback was given by each instructor to each student—hence, two sets of feedback. The students' progress was discussed by the two instructors and interventions created to facilitate learning in difficult areas. For example, in the 2009 incarnation of the course, after the first essay the instructors decided to alter the focus of the second. In this new and slightly revised assessment task, the engineering students were asked to "only deconstruct" and the social science students to "stop deconstructing and to create alternatives."

Research Approach and Scope

A combination of research approaches were used in the study of the course during the Winter terms of 2008 and 2009. I took part in the class as a participant observer both years, conducted interviews in 2008, and analysed student assignments in 2009. Two sets of semi-structured interviews were carried out at two different stages (first and second half) of the course. A total of 13 students from both engineering and sociology participated in the interviews—11 in the first round and 10 in the second, with 8 doing both. In addition, four focus groups were held in relation to the students' group projects. However, there was a fair bit of overlap in terms of participants between the focus groups and interviews, and in the end data was drawn from 14 different students. In both the interviews and the focus groups students were invited to explore their experiences of learning to see engineering through a lens of social justice. They were asked questions such as: "What was the course about?" "What do you understand by social justice?" "How does this influence your understanding of engineering?" The interviews were audiotaped, transcribed verbatim, and then analysed using a phenomenographic approach to create an outcome space for social justice. In 2009, 30 student self-reflections and critical essays were collected and analysed together with the interview transcripts again using a phenomenographic approach to sketch out eventual shifts in students' perceptions of engineering. While references are made to individual students, these should be seen as descriptions of trends in the student collective and not the students themselves as per the phenomenographic tradition. Quotations or citations taken out of context can never represent the entire category of description, nor the perception shifts associated with these.

Outcome Space for Social Justice

When the students were asked to talk about or describe what "social justice" meant to them in relation to the course and to engineering practice, nine different conceptions emerged. These conceptions are clustered together into five groups that form different positions on a spectrum of liminality—going from a pre-liminal state to bordering on a post-liminal state. A key quality that varies over the different conceptions is the students' awareness of the complexities surrounding social justice, which goes from simple and superficial to complex and deep. Other shifts are from passive to active and individual to collective. The five positions are illustrated by the quotes given below and a visual summary can be found in Figure 7.

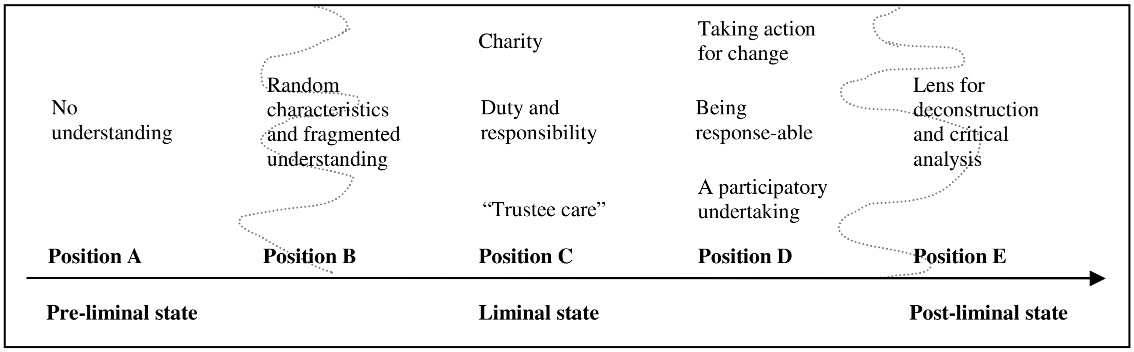

Figure 7: The outcome space for social justice for the course E&SJ

Position A – Pre-liminal state before social justice comes into view: No understanding

Some students showed at times during the interviews no or little understanding for various critical aspects of social justice. This indicates that at least some parts of the threshold had not come into view for them yet. The following quote shows this:

> **QS11:** [In response to worker recovered factories in Argentina] I'm really glad I don't live in Argentina and I really think anybody in their right mind would want to live in a society where even if you weren't per se seeing the profits, you would want to live in a society where someone was ... I don't think you can just get rid of it [hierarchical workplaces], like they did in Argentina, I would be surprised if anyone is happy with the situation in Argentina.

This student seems to miss that the main reasons behind why workers in Argentina took over enterprises that had closed down during the country's economical meltdown around the turn of the century were desperation and pure survival and not because they thought it was a better system. The "common sense" of profit making is very strong.

Position B – At the edge of the threshold: Social justice as random characteristics and fragmented understanding

At this position students spoke about social justice in general terms focusing on random and isolated characteristics which indicated a fragmented understanding.

> **QS6:** [In the first interview] I was trying to come up with an exact definition for social justice, but I don't think there is one. I think social justice is more about a broad concept than one exact definition... Like one thing I remember is the three accounting books. So that's important. So when you are making decisions as an engineer you shouldn't just try to meet the bottom line... But social justice is more than just engineering too. Like I think social justice applies to politics and social justice is sort of... It is very broad...

> **QS2:** Yeah, for sure like I always thought of social justice as like going and like feeding people like foreign aid and stuff like that, my idea of social justice now has changed in the sense that like it's broader than just foreign aid, like you can do a lot of things like with our pro bono project, it's not like we're going to a third world country and helping them with their cars and what not, we're like helping people who need to be helped and you can have social justice in your everyday life whether you live in a first world country or a third world country.

A conception focusing on random characteristics of social justice indicate that the threshold has come into view, but that the students have not yet fully entered it. They are at the border between the pre-liminal and liminal states.

Position C – At the threshold 1: Social justice as something passive and one-directional

After the very fragmented conception of social justice, the next position on the spectrum of liminality found in the study is represented by a group of three conceptions similar in complexity and characteristics.

Social justice as charity

Here students had a stronger focus on one thing they considered to be social justice namely charity or a one-way transfer of something, the act of giving. The critical aspect here is that there is a giver and a receiver.

> **QS5:** It is the same kind of idea for engineering, if we don't help them rebuild their infrastructure, who is gonna rebuild it? Who is gonna educate them? Show them that there is a better way?

> **QS9:** If we did this [the interview] in week one, you'd ask me: what's social justice? I'd probably say charity. Like giving money and just, I don't know, helping out the poor person, walking by throw them two bucks, that's social justice.

Social justice as duty and responsibility

In this conception the focus is more on the moral underpinnings of social justice rather than on a specific act. This manifests in having a duty of responsibility.

> **QS1:** The way I think about the environment is that it is here for everybody and people after I die are still going to need stuff from the environment. In terms of social justice, I'm thinking of generations past my own, what is there going to be for them? What kind of beauty and what kind of resources?

> **QS5:** It all comes down to doing what is right. Do you think it's right? Like, if you saw someone weak being bullied by someone in the street, would you do something about it? Well, you should! Morally you should do something about it. It is having the moral courage to act.

> **QS13:** Every human being has a responsibility to work toward social justice ... When I think of social justice I think of not having any negative impact on anything by anybody's actions, and that's obviously impossible.

Social justice as "trustee care" or telling people what to do

This conception of social justice is somewhat similar to charity but the focus is less on giving and more on a limited form of collaboration between giver and receiver. The giver provides the receiver with "know how" but maintains a position of power.

> **QS5:** Instead of us going in and building it for them ... it's like a mentorship program, apprenticeship as well. We take people from [local university] and teach them how to do it ... So we don't do it, we get them to do it and we pay a local elder to pay workers to do it. We show them how to do it ... trying to educate them not just doing it for them ... We have interaction with the local population. Obviously we want to build trust. Without trust nothing happens.

The three conceptions in this group represent quite simple ideas and to some extent misconceptions, e.g., Marullo and Edwards (2000) emphasise that while social justice aims to change an unjust structure, charity, whilst necessary and important, provides only a temporary solution that often ends up reproducing the status quo rather than challenging it. The students are at the threshold and try to navigate the liminal space, but some of them might get "stuck" at less complex conceptions of social justice.

Position D – At the threshold 2: Social justice as something active and participatory

After the previous group of conceptions of social justice, the next position on the spectrum of liminality found in the study is represented by another group of three conceptions similar in complexity and characteristics, but more complex.

Social justice as taking action for change

The critical aspect of this conception of social justice is that students have realised that only having a responsibility or providing help or "know how" is not enough and that more direct personal action is needed for truly promoting social justice.

> **QS12:** First of all when you know something, when you have the knowledge you can start thinking about what choices you want to make. So you take a choice, you decide to get involved and once you make a choice even then you still have to take action. It doesn't matter, I could make the choice to go help someone, but until I actually do it I haven't really done much, right?

> **QS8:** At the same time I do think that you have to feel passionate about it and I sort of realise the things that I do feel passionate about, it's not enough to just talk to them, talk about them to my friends, that I should actually be

seeking out people who might feel the same way and who are, you know, wanting to put together different initiatives to do something about it.

For this student the taking action part is also critical but the action itself involves collaborating with people to actually change how things work.

Social justice as being response-able

To be response-able means being aware of the consequences of different actions and trying to respond accordingly, i.e. to be able to respond. The critical point here is the combination of awareness and corresponding appropriate action, even if the necessary action is not clear.

> **QS7:** I feel that what I understand of social justice is what I'm doing is at the expense of others as opposed to this is what I do to help others, this is how social justice works to help people, so I guess my concept is this is what I need to stop doing, this is what I need to stop other people from doing and this is like, this is the system I need to understand and understand how to change and I understand less about what to do as an alternative you know like how to, I just know that what is happening is unjust.

The following student focused on a specific issue to point out the link between awareness and appropriate action.

> **QS3:** I don't think that you can geographically just look at one thing and see if it benefits, like have that as your scope, because there can be a lot that happens because of that outside of there. Like right now garbage is shipped to other countries and thing like that. If you just looked at Canada, you'd be like: "oh yeah we are doing pretty good for waste in Canada," but maybe that's

> because we are shipping it to other places. So I think it is completely global scale, especially in this day and age with technology that we have.

Social justice as a participatory undertaking

The critical aspects of this conception are that change comes through collaboration and that power relationships between participants need to be levelled.

> **QS8:** You realise that social justice can't come from one and it has to, it's a dynamic process where you have to communicate with people ... collaborating with different people and their ideas to synthesise all these ideas and to make sure that you know whatever practice you're doing everyone benefits.

> **QS10:** It would be sort of taking into account like a variety of perspectives and how different sorts of social, cultural, political influence ... affect those different perspectives ... I guess it's taking into consideration like the broader social influence that impact a variety of people as opposed to speaking of it as a top down theory. [**I:** So more bottom up?] Yeah.

> **QS3:** In the context I've been using it, like through the civil department there is humanitarian engineering work that is done, which is mainly in third world type countries, and helping to implement new technologies, but in a way that's because of their needs ... not coming in with technology that we think is great for them, things that they need and are relevant to their community.

The three conceptions of social justice in this group represent more complex ideas than those in the previous group. Here social justice is more of an active and collaborative process. These conceptions correspond to positions further along the liminal spectrum, but the students have yet to truly exit the threshold and adopt social justice as a lens for their future practice.

Position E – Exiting the threshold: Social justice as a lens for deconstruction and critical analysis

The critical aspect of this conception is the insight that awareness about, for example, social injustices can only be gained by critical analysis and deconstruction of what one takes for granted. While some of the earlier dimensions highlighted the role of awareness, this dimension highlights how awareness can be achieved and also how appropriate actions can be devised.

> **QS9:** You should try and see what actually caused this to happen, cause if it burst once it can burst again and the same thing with social justice and charity is that if you just kind of perform charity acts, yeah you might have helped one person in one situation, but who's to say the underlying factor won't cause the exact same thing to somebody else. So social justice, social change is trying to figure out well what's the fundamental problem or what's the root cause of … what you're seeing.

> **QS8:** I think that it's really important that different people from different faculties sort of break down the boundaries between them and come and together and learn a lot about other things that you normally would have certain assumptions on.

In this conception social justice is seen as a new lens through which to look at the world. While the conceptions of previous groups correspond to increasingly complex ideas of what social justice entails, the focus has been mainly on growing awareness about the nature of social justice.

In contrast, this conception represents a new way of seeing in which students apply their knowledge to their own lives, practice and profession. Students who internalise this conception of social justice will have passed or be on the verge of passing the threshold.

Summary of the outcome space

In summary, different conceptions of how the students conceptualised social justice go from simple toward more complex understanding and the variation along the spectrum of liminality helps to illustrate how the students pass through the threshold. The conceptions cannot be seen as a linear progression since they both overlap and can exist simultaneously in how a student views social justice. This mapping of the liminal space of social justice is in line both with the phenomenographic idea that students can hold several conceptions of the same phenomenon simultaneously and the idea of oscillation between different liminal states suggested by threshold concept theory. Students will take different paths over the threshold and some students might get "stuck" at less complex conceptions unable to fully cross.

Shifting Perceptions of Engineering

In addition to studying students' conceptions of social justice, the ways in which students' perceptions of engineering were shifted by the crossing of the threshold were explored. In line with Freire's (1970) *conscientização* the aim of the course was not only to raise awareness among the students, but also to help them engage with the issues raised and shift their ways of looking at themselves, their profession, and the world. Engineering and non-engineering students' perception shifts are discussed separately. Table 2 summarises the findings.

Shifts in How Engineering Students Perceive Engineering A – Critique of the hegemony of engineering education B – Critique of the hegemony of the current profit paradigm of engineering C – Critique of the notion of a "right answer" D – Critique of the "common sense" of technical solutions E – The need for engineers to be humble and open for critique F – The need to ask who do we, as engineers, engineer for? G – The world is confusing and how do we as engineers fit in? **Shifts in how Social Science Students Perceive Engineering** α – Breaking down stereotypes about engineer/s/ing β – The realisation that engineering can play a positive role in the creation of alternatives

Table 2: Emerging perception shifts of engineering

Shifts in how engineering students perceive engineering

Among the engineering students in the class, seven different but related, perception shifts of engineering could be discerned. The theme running through all of these were the deconstruction of the students' original perceptions of engineering.

A – Critique of the hegemony of engineering education

> **QSR13**: 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 feel as if this class has helped me to be more critical of different situations I face and I found that this class was very informative and eye-opening.

Here the critical aspect is the focus on how current engineering education promotes a certain limited way of thinking, which, for example, favours problem solving over problem posing.

B – Critique of the hegemony of the current profit paradigm of engineering

> **QS9**: It's the social, environmental and economic… some companies have tried to go for it, but 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.

Here the critical aspect is the focus on how current engineering practice usually is strongly aligned with a purely economical perspective on the expense of social and environmental considerations.

C – Critique of the notion of a "right answer"

> **QS14**: [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.

Here the critical aspect is the focus on how there exists in engineering education a notion that there always is a "right" in any given situation rather than that there can be several "right" answers depending on one's perspective and context.

D – Critique of the "common sense" of technical solutions

> **QSR11**: 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. … [The project] has changed my perspective on social issues and has led me to believe that the engineering approach to problem solving taught at [University] is generally not the most comprehensive and is severely lacking in social considerations when working in the "real world" outside of school.

Here the critical aspect is the focus on how engineering practice centred on solely technical solutions will be severely lacking for adequately addressing most situations involving people and how a more holistic approach is needed.

E – The need for engineers to be humble and open for critique

> **QSR7**: [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.

Here the critical aspect is the focus on how engineers need to realise that while they might identify as problem solvers they do not know everything and need to be humble and open for critique to be able to find appropriate "solutions."

F – The need to ask who do we, as engineers, engineer for?

> **QSR3**: When brainstorming ideas for a product design for our project I couldn't simply suggest for example a chair as I would normally do in a brainstorming session. I had to stop, think, and deconstruct my suggestion before suggesting it to the group. I had to think who the chair was for, was it useful for Argentineans? Was there a market?, would the cartoneros benefit from a chair? This differed completely from an engineering brainstorming session where I would suggest anything as long as it could be physically manufactured in an engineering context.

Here the critical aspect is the focus on how engineers really need to consider who they are creating solutions for, i.e., "Who is the audience?"

G – The world is confusing and how do we as engineers fit in?

> **QS7**: I think the lasting impression is going be that I need to do a lot of thinking about what I'm going to do after I graduate. And I think as of most of these issues that aren't engineering issues, where you walk out and say okay one plus one equals two. 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.

Here the critical aspect is the question of how one as an engineer fits into a world which seems more complex and confusing than before and the growing realisation that most issues in the world are not engineering issues.

Summary of the engineers' perception shifts

These seven categories indicate that it is possible to shift engineering students' perceptions of their future practice and profession and that the course is successful in helping students deconstruct their previous understandings of engineering. In fact, this could be seen to happen in practice in the students critical response essays. This is illustrated by the following excerpt where an engineering student deconstructs the taken-for-granted assumptions underlying a sentence through a series of questions:

> **QCRE1**: As an engineering student, I feel that the term technology is closely related to the process of engineering. *Why are technology and engineering closely related?* At school I spend 99% of time learning about different technologies and I am told that they are important. *Why is all my time spent learning about technology?* I suppose society feels that technology is important as it advances things forward. *Why does technology equate to advancement?* I remember this being discussed at the beginning of the course. This viewpoint is the result of modernity which is part of the dominant discourse (Course instructor in class discussion).

However, here it is important to point out that the success of the course is not in getting students to critique existing good practice, but to develop the skills of critique so that taken-for-granted assumptions can be questioned and appropriate choices made about the future. For example, if students assume that technology equals advancement then they might ignore the problems of environmental impact of those technologies.

Shifts in how social science students perceive engineering

In contrast to the engineers, most of the social scientists in the class had no or little actual understanding of what engineering really entails. As one of the sociology students put it "A good majority of us and myself, really have no idea in terms talking about engineering. I was going into this course and … actually had no knowledge of engineering." However, two different but related shifts in how these social scientists perceived engineering and engineers due to the course could be discerned. The first focused on breaking down stereotypes and the second on the positive potential of engineering in the creation of viable alternatives to current practices.

α – Breaking down stereotypes about engineer/s/ing

> **QSR18**: I remember when I first came into this class, I had no idea of what "engineering" actually was, beyond the chants we sang about engineers who should "go build a bridge and jump off it." In some ways, my definition of what engineers do has become even more confused, but in others I've grasped the breadth of knowledge and expertise that engineers bring to their own field of study, which happens to be as or nearly as widespread as the liberal arts programmes. Along with this diversity, I have also began to recognise the difference among each engineer I've gotten the chance to know—it turns out they aren't just one big group of partying, conservative, clones after all!

For the social scientists, the course offered an opportunity to work with engineering students in a constructive manner that in many cases resulted in the breaking down of (negative) stereotypes of engineers and engineering. This is an important first step toward grasping any positive potential engineering has to offer.

β – The realisation that engineering can play a positive role in the creation of alternatives

> **QSR14**: Participating in this class this semester has definitively been an eye opening experience. I came to the class thinking I knew what "social justice" was and how it should be approached. However, I have come to realise that social science students are often given the tools to deconstruct an issue, but have no ability to directly apply it in the real world. Working with engineers has most definitively created and developed this balance. Overall, this class has taught me not only to think but to think and act.

> **QSR2**: … during this idea generation stage I realised that there will never be a perfect option, however unlike in sociology where one can simply deconstruct—engineers are trained to construct. Therefore I had to force myself from rejecting every idea that was suggested and try to decide on one that seemed like the "best" option.

Some non-engineering students moved beyond the breaking down of negative stereotypes to the realisation that engineering can play a positive role in the creation of viable alternatives to current practices and that engineers possess skills and ways of thinking that complement those of social scientists in a potentially beneficial way.

Summary of the social scientists' perception shifts

Among the social scientists, two perception shifts or categories (of description) of engineering were found. The first one focused on breaking down stereotypes and can be seen as a pre-requisite for the second, which focused on the role of engineering in the creation of alternatives. These two categories indicate that it is possible to shift non-engineers' perceptions of engineering and its potential from ignorance to more complex understandings. In fact, this could be seen to happen in practice in the students' critical response essays. Here is an excerpt showing how a developmental studies student, who has been trained to be sceptical of "technical" solutions, imagines the educational potential of a modified "One Laptop per Child" project.

> **QCRE10**: Despite these weaknesses, the creation and distribution of the XO laptop provides a piece of technology that easily records and transfers knowledge between children in various places of this earth. Children in economically capable positions now receive a valuable opportunity that they might not otherwise have had, an opportunity to learn valuable knowledge from other children their age while possibly redefining education outside of their own conceptions of it. Education will no longer be an individualistic process but a collaborative activity. This collective activity no longer devalues previous forms of education and knowledge that are different from the standard provided.

Based on the findings presented above, the conclusion can drawn that the course studied is capable of shifting the perceptions of engineering held by both engineers and social scientists in ways that can provide a common ground for starting to work together to address some of the pressing challenges facing humanity. However, this course only provided the first necessary step.

The dynamic of truly reciprocal collaboration between engineers and social scientists is still an open question.

Concluding Summary and Reflections

In this study two themes were explored: students' conceptions of social justice and eventual shifts in perceptions of engineering. Courses such as the one studied can help students get a deeper understanding of the complexities of social justice, but there will be significant variation in the ways students cope with the task of seeing engineering from a socially just perspective. Developing the students' ability to think critically is one key aim of the course, but it is clear that not all students are achieving this goal. One of the purposes of this study was to explore the dimensions of variation in the way students conceptualise the phenomenon of social justice with regard to engineering, in order that the results might throw some light on ways of approaching the teaching in future years. This will be expanded on in latter chapters. Applying a social justice lens to engineering will most likely problematise the profession and highlight many of the complexities surrounding engineering practice. Questions raised in such a process might shift how engineering students view their future practice and profession. For non-engineering students the same discussion and the sharing of a classroom with engineers potentially will lead to new insights about engineering. The findings presented above suggest that it is possible to shift the perceptions of social scientists and engineers and to create a way forward for the deconstruction of engineering "common sense" and the creation of positive alternatives. This is also reflected in these student quotes:

> **QSR9:** This course has opened my eyes in making me see that there are many different views in the world and that there are no universal solutions or methods when dealing with a problem.

> **QSR10:** The structure of the class has been an example of “what could be!” I believe this course is the best and most important course I will take at this strange institution and probably the most influential. Every time I left class I felt like I my brain had really expanded and I was really learning. This process continues outside of class and my passion continues to grow. I have been greatly inspired by the both of you [instructors] and my learning in this class, thank you very much for this.

Engineers and social scientists can help each other cross this threshold and create new possibilities for the future of engineering.

Chapter 5

Exploration of Social Justice in a Sustainability Classroom

There is a possibility (as argued by the course instructor later in this chapter) that social justice for some people might carry negative connotations and thus make them less likely to engage in a constructive discussion about issues connected to social justice, which leads to the question if there is another term that might be used that is not as value-loaded. This chapter reports on an exploration of to what extent and in what ways a course with a main focus on sustainable design (or more generally sustainability) expands students' understanding of social justice and ability to think critically. According to Nieusma (2009):

> Over the past decade, the concept of "sustainability" has gained increasing attention across society at large and within many educational institutions. As the problems associated with globalized industrial production and the energy-intensive consumer economy worsen, new models for addressing human needs continue to arise. Given the central role of engineering in creating the tools of industrial production, distribution, and even consumption, it is not surprising that increased attention to sustainability is also evident among engineering students and educators. (p. 1)

What does sustainability mean then? Nieusma points out that a reoccurring theme is attention to the intersections of social, economic, and ecological systems. This is reflected in the spin-off concept of the "triple bottom line," which "adds social responsibility ... and ecological responsibility ... to economic viability ... as the underlying criteria by which organizational performance should be evaluated" (p. 2). Drawing on Catalano and Baillie (2006) the question if having a responsibility is enough or if something more active is needed can be raised. A more operational model can be found in Franklin's (1999) idea of three bookkeeping books: one for economy, one for people and social impacts, and one for environmental accounting.

In terms of the relationship between social justice and sustainability a parallel can be drawn to Boff (1997), who argues that it is the same logic that has lead to the devastation of the environment that lies behind the exploitation of the marginalised. Marcuse (1998), on the other hand, points out that "sustainability and social justice do not necessarily go hand in hand" (p. 103). Furthermore, Marcuse (1998) argues, in the context of urban development, against conflating the two terms or replacing social justice with sustainability.

> We should rescue sustainability as an honourable, indeed critically important, goal for environmental policy by confining its use only to where it is appropriate, recognizing its limitations and avoiding the temptation to take it over as an easy way out of facing the conflicts that beset us in other areas of policy. If we do feel called upon to use it in the area of social policy, it should be to emphasize the criterion of long-term political and social viability in the assessment of otherwise desirable programmes and not as a goal replacing social justice, which must remain the focal point for our efforts. (p. 111)

However, the aim of the instructor of the course studied was not to replace or conflate terms, but rather to introduce the students to a discussion about the cultural and political underpinnings of sustainable design which for him is a similar discussion to a discussion centred on social justice. This will be further expanded on below.

This chapter is broken down in the following way: First, the course, its context, and the research approach used are described. Then, the findings of the study are presented in the form of outcome spaces for sustainability and social justice and observations about the relationship between these two terms as well as the role of critical thinking in the course. The chapter is concluded with a summary and some reflections.

The Course "Sustainable Design Politics and Culture" and Rensselaer

The course *Sustainable Design Politics and Culture* (SDPC) was created and first taught in 2008 by Dean Nieusma of Rensselaer Polytechnic Institute (RPI), Troy, United States. Traditionally, RPI mainly has been a technical school, but more recently there has been an ambition to expand the curriculum to include a wider range of disciplines outside of engineering and science. Engineering programmes still dominate in terms of student enrolment (D. Nieusma, personal communication, Fall 2008). SDPC is a Science and Technology Studies (STS) seminar aimed to help students realise the limitations of technical solutions toward a sustainable society and the need for changes in individual behaviour and at an institutional level. In addition, the course intends to provide students with conceptual tools to understand social power using sustainability as a lens. This upper level course is interdisciplinary in nature and at the time when this study was carried out the student composition was as follows: ten engineering and information technology majors, five architecture and design majors, and one science major. The class had an equal number of women and men. The majority of the students were in their final year while two engineers were in their second year. 15 out of the 16 students completed the course (Nieusma, 2009). The class met twice a week.

The course was broken down into three units: 1. an orientation to sustainable design and its practice; 2. a look at specific contexts and cases of sustainable design practice; and 3. strategic pathways to achieving a more sustainable future. The aim of the orientation unit was to give the students the conceptual tools they need to carry out their individual research case studies of existing examples of sustainable design practice (or the lack of). This unit was centred around three lenses to sustainability: individual behaviour change, technical innovation, and institutional innovation, which were explored through a mix of common and individually picked readings. The second unit was centred around the students' individual case studies and the third was centred around their strategic pathways essays. In addition to these two major assignments, the students were required to write ten research updates based on their readings throughout the semester. Classroom discussion was the main mechanism of the class, in addition to the quite extensive readings and course assignments. Here, the course instructor took the role of facilitator, allowing the students to drive the discussion while helping them along by asking probing follow-up questions when needed. Overall, the class required a high level of student autonomy and responsibility.

The Role of Social Justice in the Course

As indicated by its name, the main themes of this course were issues connected to and surrounding sustainable design or more generally sustainability. The course instructor expanded during an interview on the role of social justice in the course, the ways he saw it intersect with the main themes of the course, and what he tried to achieve.

> **SDPC_I:** Although social justice questions are central to my scholarship and to my teaching, I very, very rarely use the language of social justice. I do sometimes use the language of equity, but not very often. What I try to do is provide students: 1. the conceptual tools to understand social power, 2. the space to have discussions where that becomes a relevant method to understanding the world, and 3. topics or content that's not about social justice, but has the potential to become a conversation about social justice by

its nature. So sustainability, you can't go very far in talking about sustainability before you start to talk about who has what and why.

He also differentiated his approach from other approaches aiming to highlight issues connected to social justice.

SDPC_I: I definitely don't do old school social justice where we say here are those people who don't have anything, and here are the people who have a lot of things, and those people need to give some of their stuff to these people, I don't approach it that way, but we have talked a lot about the responsibilities of the developed countries to the developing countries.

The instructor explained his rationale for avoiding using explicit social justice terminology in the following way.

SDPC_I: I told you I like to back students into this [the topics of the course] rather than push it down their throat, but with social justice in particular it raises all sorts of concerns and people shut down, and the reason is this, social justice is a code word for saying, "hey I'm going to be critical about what you're doing because I'm recognising that it affects other people," and that makes a lot of people feel insecure.

The instructor later returned to the interconnectedness between sustainability and social justice and how he strived for creating an inclusive learning environment that allowed for a broad conversation that could include social justice.

SDPC_I: I really do think it's the same conversation with different language, and I guess personally I tend to teach to the middle, to borrow a bad phrase

> from the political race, so that students who would normally be turned off by social justice language are invited into the conversation, but also students who want to talk social justice have permission to use that language.

Out of the class sessions I participated in, social justice was only focused on in an explicit manner twice, once when the students where asked what links they could see between sustainable design and social justice, and once in a guest lecture late in the term, where I talked about the early stages of the research presented in this dissertation. Other than this the presence of social justice in the class was what the students inferred indirectly from the conversations and readings about sustainable design. For the course instructor social justice and sustainability are inherently linked, but the question is if the students saw these links. The instructor thought they did to some extent. In light of the discussion above it was of interest to explore what conceptions of social justice the students in the class might hold while participating in the course.

Research Method

Data collection for this study was carried out in the fall of 2008. I attended the course once a week as (participant) observer for most of the fall term (week three to thirteen out of fifteen). In addition to classroom observation, data was collected in the form of student interviews and student course assignments. Students were invited to take part in interviews about the class and those who took part were asked if they were willing to share their assignments with the interviewer. Ten (out of fifteen active class participants) students from different disciplinary backgrounds were interviewed throughout the term (from week five to thirteen) and assignments were collected from eight of these ten. The interviewees were asked questions such as “What is the course about?” “Based on the course title what did you expect the course to be about?” “Has the course had any impact on how you think about your future profession and career and if so how?" "What do you understand by sustainability?" "What do you understand by social justice?" and "What connections do you see between sustainability and social justice?" The interviews were audiotaped and transcribed verbatim. The interview transcripts were analysed using a phenomenographic approach. The questions "What is social justice?" and "What is sustainability?" guided the analysis. The iterative analysis process continued until emerging themes could be formalised into two separate liminal outcome spaces—one for social justice and one for sustainability. In addition, student perspectives on the relationships between these two terms and the role of critical thinking in the course were also explored.

Findings

The outcomes space for sustainability was directly located in the data whereas the outcome space for social justice (related to sustainability) had to be inferred more indirectly from key indicators. Different dimensions of sustainability were taken into account, but the main interest was issues relevant to the social dimension of sustainability. Both outcome spaces represent a mapping onto a liminal space and both seem to converge toward a point of heightened social awareness manifested as a wish to improve society. It is important to remember that these mappings correspond to trends on the collective level among the students and not individual learners' progression through the liminal space. Neither does the structure of the outcome spaces suggest that the act of learning is linear.

Outcome Space for Sustainability

Based on how the students talked about sustainability and the course, seven liminal positions were identified corresponding to increasingly complex conceptions of sustainability with a growing emphasis on the social dimension. The different liminal positions are illustrated by the quotes given below and Figure 8 represents a visual summary of the outcome space.

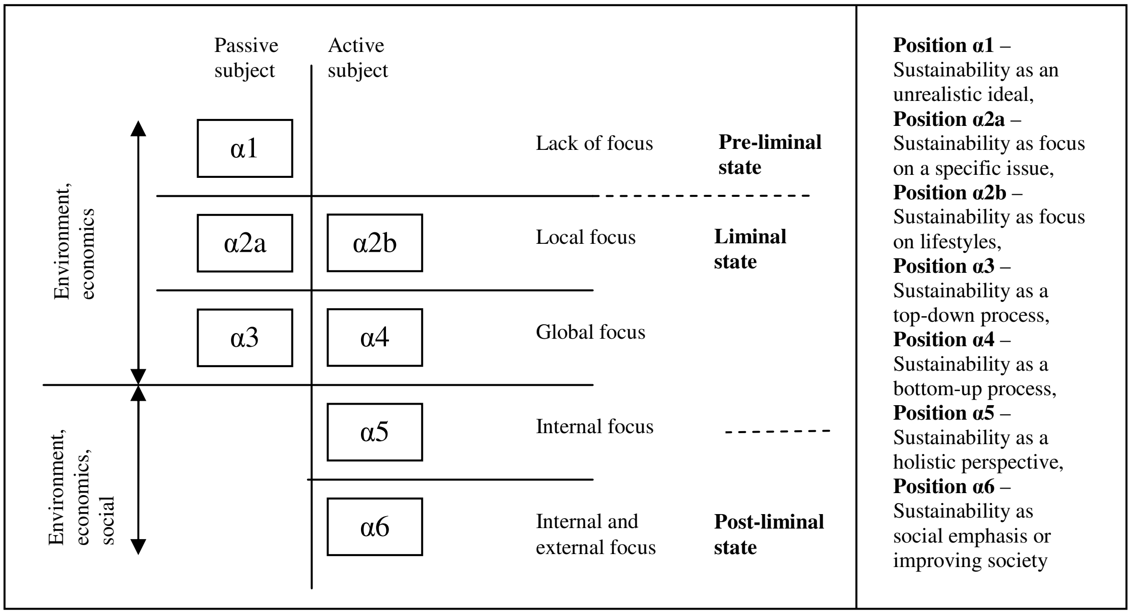

Figure 8: The outcome space for sustainability for the course SDPC

Position α1 – Sustainability as an unrealistic ideal

Here students talked about sustainability as a naive and unrealistic ideal associated with "flaky" people far removed from the students' own "common sense" understanding of the world.

> **RS1:** When I think of people that advocate sustainability right now I do kind of consider them flakes because they're very isolated within their studies, this is what they're passionate about, but they don't really have exposure to how to integrate it into the real world. [E.g.] where the people move and they give up everything and they're like a commune, I mean that's a great way to advocate … sustainability, but is it really feasible within the way the world works? I don't really think so … the way that the Nation's built and companies make money and people can merge into the middle class.

This is an example of a pre-liminal position where the concept or part thereof has not yet come into view. There is no active subject and sustainability is associated with other people. Environmental and economical terminology is used.

Position α2a – Sustainability as focus on a specific issue

Typical for this position is the focus on a particular dimension or aspect of sustainability such as environmental concern or technological solutions.

> **RS8:** There's a machine that can sequester one ton of CO_2 a day. I mean even if all the cars were taken off the road right now CO_2 levels would still be going up, and if we're really serious about talking about it we're going to need to actually start sequestering CO_2, and in terms of global warming that's one answer, it's not a cheap answer but it's … for example it's the best thing on the table right now.

> **I:** So if we don't prioritise sustainability what do you believe would happen?
>
> **RS4:** I mean pretty soon into the future I think we're going to be facing more and more problems with global warming, with hurricanes, and droughts, and loss of species, which some of them may be less important than others but it just, they all work into the system that is kind of slowly falling apart and we're a part of it.
>
> **I:** We humans as a species will get into trouble eventually if we don't do anything about it?
>
> **RS4:** Yeah.

Position α2b – Sustainability as focus on lifestyles

This is a similar position to the previous one as students focus on one aspect of sustainability, namely sustainable lifestyles or changes in individual behaviour (of oneself).

> **RS5:** [A text we read] said the most important thing is what you wear and what you eat, those are like the most important products to pay attention to … it's definitely compelling me to think about … what I buy yeah that is making an impact, I think I really will try once I have some more time to go to the farmer's market here in [City] and buy stuff there instead of buying the produce in the store.

> **RS2:** I try to practice all the stuff myself personally; you know the use of plastic bags, the use of bottles … he asked us how do you contribute personally to sustainable design, and my contribution was I bike to and from campus. So I think I'd like to adopt as many ideas as possible or as many like changes. So I know I said the lifestyles thing is most important. The stuff is part of lifestyles, like how do you live your, how do you shop from now on by using not plastic bags but by using like a reusable bag.

The main difference from the previous position is that here the subjective self is more active and have a more personal connection to sustainability, e.g., *my impact*. However, the focus is still quite local and does not challenge or change systemic issues.

Position α3 – Sustainability as a top-down process

This position marks a shift toward a broader perspective and actually changing systemic issues. Here sustainability is seen more in terms of institutional or governmental policy.

> **RS8:** Well I mean for global warming I mean you had the [name] standards … it's basically the fuel efficiency standards for vehicles, and that's mandated by the federal government and that hasn't gone up for awhile and now it's starting to go back up. Those would certainly help those types of constraints where you give a company you need to do this and then they work within that because everybody's on the same level playing field, there's no competitive advantage.

> **RS1:** Sustainability itself I think it's an important topic. I think it has to stem from the top down because I think people in corporations are fundamentally self-centred … I think maybe government should regulate the industry, like I said earlier in class about having constraints for people … and businesses to operate in … They're still operating within certain constraints right now and they still manage to make money. So I think if there were sustainability constraints put on corporations and people's lives we would adapt and function and everything would still work.

Here a shift from local to global and more emphasis on change on a scale beyond the individual can be discerned. However, in comparison to α2b there is no agency and people are seen as passive receivers, e.g., little ownership of sustainability. Sustainability is still mainly described in environmental and economical terms.

Position α4 – Sustainability as a bottom-up process

This position follows on form α2a and α3 with subjects now active (collectively) to bring about systemic change. Institutions such as governments still play an important role, but the initiative can come from individuals/active subjects.

> **RS10:** Right now, right now what we're looking at is the pathways to sustainability, most of them I found are about community based participation, a lot of it is all about collaboration, grassroots movements, I mean like people being active in the Government to get the Government to promote green or sustainable policies so I assume it's … a lot of it, a lot of sustainability is social … I think before the course I wasn't so much aware of the social aspect of it.

> **RS9:** Yeah the case study I chose to do was on grassroots movements in California directly related to electronic waste, so the release of chemicals in the manufacturing process of semi-conductors and hardware, computer hardware in particular, and how a lot of these localised groups saw this getting leaked into their, you know, water supplies and harmfully affecting them and the workers at the factory and things of that nature, and working with government groups like the Environmental Protection Agency ... and how they from the bottom-up have affected markets to actually change, things like that.

This position represents much more active subjects who take more personal responsibility for promoting sustainability. A social dimension is added to the environmental and economic descriptions of sustainability.

Position α5 – Sustainability as a holistic perspective

Here students start to see sustainability as something internal, namely an approach or lens to adopt. Key is the idea of drawing on multiple perspectives or tools, with the simplest incarnation being the "triple bottom line" approach to sustainability. However, the students in the class emphasised the importance of seeing how things fit together and understanding root causes. This corresponds to the critical thinking skills the instructor desired them to develop.

> **RS7:** I think it's probably helped me to look at a bigger picture instead of focusing more narrowly on one thing. It's because sustainability it's not about this one thing, it's on this one thing and everything else and all the impacts and how everything kind of meshes together. So I've never really had to look at that really huge picture before. So I guess that's been helpful.

> **RS10:** Whenever you look at design, the new trend in design or some of the new trends, I don't know exactly how old it is, what I've learned is you really have to … when you're approaching a problem you look at all the different elements that come into the problem, otherwise, you're not going to really get to find a solution. It could alleviate some of the symptoms, but it won't actually be a solution which is kind of what sustainability is all about, getting to the root of environmental, social, economic, what's wrong with the system, not necessarily this particular part of it. … You're trying to address the systemic issues.

As this position more or less corresponds to the course objectives, it can be said to belong to a post-liminal state or at least border to this. The social dimension of sustainability is further emphasised.

Position α6 – Sustainability as social emphasis or improving society

This position includes further social emphasis and, rather than just understanding the complexities of sustainability, subjects move on to actively work to improve society. This is in a sense a continuation from α4.

> **RS10:** I found that whenever you learn about sustainability some of the problems like consumerism and just the way we live our daily lives it's kind of hard to ignore them once you know them. It makes you think more about the solutions and what changes you can make, and that's really how our society is going to have to make progress.

> **RS8:** I mean what comes to mind immediately is like third world countries where people don't have like the food live or the water to drink and the chance to give their kids a future … there's another student in class that, I mean he made the point that he doesn't see how social justice affects sustainability at all … It's like well they're two completely different things. I mean you have the ecology of the system and then you have the social justice aspect … like I said I try and take a longer view and … you have a set of people that are consistently not allowed to express themselves or not allowed to be a part of a larger society, there's going to be a point where you just can't do that anymore, and I think that's part of sustainability is you have to work towards that point where what you're doing now if you were to keep doing it would be okay you always strive for something better.

This position is internal and external in nature in relation to the subjective self; internal for further valuing the social, but also external, as in *working for change*. This is a distinct post-liminal position in terms course objectives and there is a relationship forming between social justice and sustainability.

Summary of the sustainability outcome space

The outcome space that emerged from the data consists of seven liminal positions that reflect an increasingly complex understanding of sustainability. The three (pedagogical) lenses—individual, technical, and institutional—used by the course instructor and the perceived need for a more holistic approach to sustainability or sustainable design are reflected in the different liminal positions. The course clearly was successful in helping some of the students understand the need for more multifaceted approaches to sustainable design as well as linking sustainability to social change. There were several referential and structural shifts (Marton and Booth, 1997) in the students' ways of experiencing sustainability. The most prominent of these being: a shift from passive to active subjects, shifts from a lack of focus to more general outward focuses to an inward focus to finally an integrated internal and external focus, and an increasing emphasis on the social dimension of sustainability in addition to the environmental and economic dimensions.

Outcome Space for Social Justice

Based on how the students talked about social justice or what could be interfered indirectly form other topics, five liminal positions of increasing complexity could be sketched out. The different liminal positions are illustrated by the quotes given below and Figure 9 represents a visual summary of the outcome space.

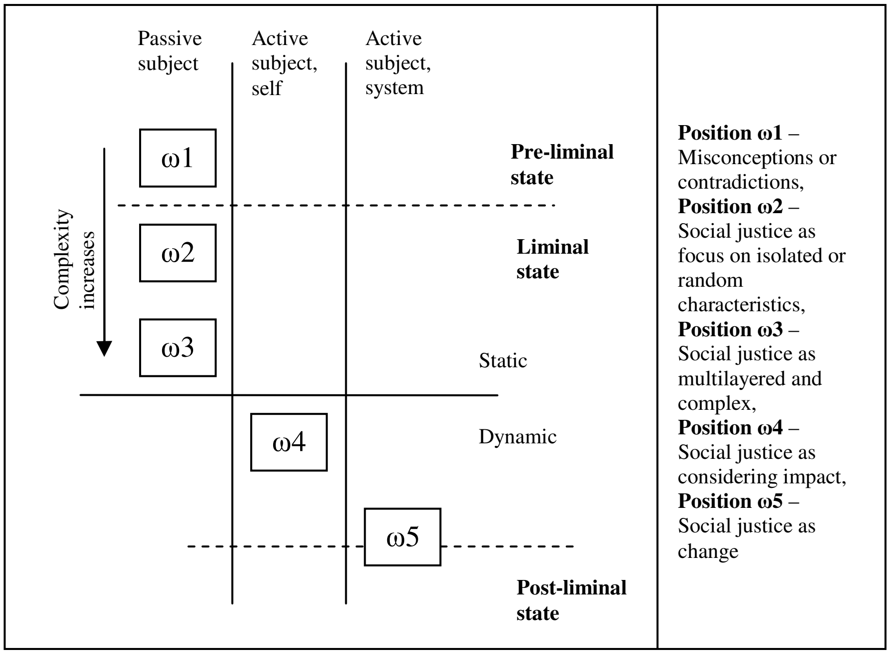

Figure 9: The outcome space for social justice for the course SDPC

Position ω1 – Misconceptions or contradictions about social justice

Some students would at times express clear misconceptions about social justice or ideas that contradicted critical aspects of social justice. These contradictions could take the form of social Darwinism, popular justice, the superiority of western freedoms, or the inevitability of the status quo.

> **RS4:** It's kind of what I said before just assisting ourselves and our perspective is really complicated because … just that we try so hard to sustain every living person and in turn we kind of turn off the cycle of evolution. I'm kind of into this because I've taken some biology classes in ecology and things, but I just think it's interesting. We just try to keep everyone alive, but now there's no competition and we don't evolve and I don't know.

> **RS6:** Social justice, I think of if someone committed a crime and they weren't arrested for it you'd take it upon yourself to get back.

> **RS1:** Look at the Middle East, these people have all the oil and they live ass backward lives … and they're not really, at least from the American perspective, progressing at all. There's no freedom, their people are not considered equal.

> **RS1:** Yeah I think that it's kind of screwed up that Americans live excessively, but I don't really feel guilty about it. I don't know, I mean you could really kill yourself over if you really had some sort of conscience for social justice. There are people in the United States of America that don't live well. I mean it's just how it is; I guess it's the way the world is. I'm lucky to be born into the family that I am. I'm lucky to have a work ethic.

This clearly is a pre-liminal position where central characteristics of social justice yet have to come into view.

Position ω2 – Social justice as focus on isolated or random characteristics

Some students discussed social justice in general terms, focusing on isolated or random characteristics. Some themes that emerged were: the rights of humans versus the environment, equality, and caring for others.

Rights and the environment:

> **RS6:** Oh it's starting to come back to me now, we did a reading on social justice and … it talked about giving everyone the ability to be green … It's

probably a compromise somewhere in the middle. I mean at this point I don't know exactly to the extent of how bad global warming is, but it seems like it's very bad, getting worse and there's no positive future in sight. If that's true then we need to put the environment in front of people or else there won't be people to care about in the future, but it kind of goes hand in hand, if you help the environment you help people.

RS3: … social justice in the Enlightenment in humans and above all the rest, and then we kind of realised through the industrial revolution that we're ruining our environment and our planet, and then comes ecological justice, and then that's where they butt heads because this one was defined before the first and being social justice as I have the right to live and breathe how I will.

Equality:

RS1: It's not fair for somebody who can't afford healthcare to not be able to get it, especially because it's so accessible and so many people can't afford it, and probably the cost of it wouldn't be nearly as much as we think it would be. I mean ultimately it boils down to dollars and cents just like everything else does.

RS5: I was like okay well how do these two social justice issues … giving parents, mothers, day-care at work for the kids, like that seems like an equal thing to do so that they have as equal of an opportunity to work as men.

RS8: I mean what comes to mind immediately is third world countries where people don't have the food live or the water to drink and the chance to give their kids a future.

Care and respect for others:

RS5: I think social justice then is about people caring for each other and taking their neighbour into as great consideration as their family.

RS7: I thought that for someone to truly think about treating nature with respect … can people really do that when they readily abuse other people? Can you achieve one respect, that overall respecting people?

At this position the students have entered the liminal space of social justice, but have not advanced that far. Distributive and relational dimensions of social justice (Gewirtz, 1998) are mentioned, but separately and on a general level. Social justice is generally not linked to one's subjective self.

Position ω3 – Social justice as multilayered and complex

At this position the focus was on social justice having different components or layers and about how these influence each other.

RS10: I think the main connection between social justice and sustainability is that they all are built upon the same factors. Like social justice has an economic component and an environmental component … a technological component, like what technologies do people have access to, do they, can they afford that sort of thing?

> **RS5:** It [has] definitely solidified the fact that sustainability is about social sustainability too. Making communities and social situations sustainable, because no matter what everything's linked and … inequity in social situations between humans is also going to lead to inequity in the way we treat our environment.

> **RS9:** It's more of how directly or indirectly something affects you in a way that it wouldn't affect necessarily someone else … if you wanted to go with injustice, I would not necessarily be equally impacted by … being able to eat because I can afford to feed myself and necessarily if I was in a different social status or a different social standing or a different cultural standing that may not be the case so that imbalance is where the influences take hold I guess.

This is a more advanced liminal position where the students' understanding has shifted from a singular, but quite general focus, to more complex relationships. Social justice is still talked about mostly on a general rather than a personal level, i.e., more focus on others than the self. The relational and distributional dimensions are preset, but still mostly talked about separately.

Position ω4 – Social justice as considering impact

Central to this position is to consider the impact or consequences of one's actions (e.g., design choices) and to make these positive in terms beyond simple profit.

> **RS10:** I guess the main thing that I understand about social justice is trying to at least consider it when you're making a design. You can design for the industrialised world, but at the same time what else could this product do?

> Because one of the things I learned when I went into the PDI program is if you design for the lowest of the people it's also going to work for everyone else. So you can get some really amazing solutions out of that. When you make a really simple solution and it can be effective for everyone.

> **RS9:** It will most definitely be part of my thought process from here on out, understanding a bigger context of what I do and how I can at least improve marginally or influence … that is my goal. So I would definitely bring that from this class to actually say here's our problem, we could fix it this way, we have the most harm we can possibly induce or I'm making this small simple change, we're contributing to a better push, we'll be influencing other people to do the same at a higher level let's do that versus this, and having that reasoning and that rationale I think is definitely a positive thing.

Yet another more advanced liminal position where the main difference from ω3 is the focus on the subjective self, i.e., taking responsibility for one's actions.

Position ω5 – Social justice as change

The focus on this position is on changing or improving society.

> **RS8:** I try and take a longer view and if you have a set of people that are consistently not allowed to express themselves or not allowed to be a part of a larger society, there's going to be a point where that's, you just can't do that anymore, and I think that's part of sustainability is you have to work towards that point where what you're doing now if you were to keep doing it would be okay you always strive for something better.

> **RS10:** In that way it's sustainable and social justice at the same time. You have to take everything into consideration, pull it all apart and find out like what's really the problem so you can get a simple solution out of that and then build it off of that to get something really, that works.

> **RS10:** I think it's promoting community based organisation … I think part of it is re-establishing part of the culture that we've lost through the industrial revolution. The way people interact with each other, with the broader community, and just how they live their daily lives, trying to rebuild more thoughtful living I guess.

This is a position that at least borders onto a post-liminal state of social justice as the focus to some extent is on changing the current system. This is the most active position in comparison with the previous understanding of complexities (ω3) and considering personal impact (ω4). The relational and distributional dimensions are yet again present.

Summary of the social justice outcome space

While this outcome space did not emerge as clearly as that of sustainability, five liminal positions corresponding to an increasingly complex understanding could be sketched out. As there was little explicit focus on social justice in the course, no direct correlations between the outcome space and course elements can be discerned, except possibly an increase in social awareness. Overall, the outcome space is quite general in nature, but a few referential and structural shifts in the students' ways of experiencing social justice can be identified, such as a shift from passive to active subjects and a shift from a unspecified focus to a more systemic focus. Most students spoke of social justice as quite static in nature rather than something dynamic and participatory.

The Relationship between Sustainability and Social Justice

In some of the interviews, the relationship between social justice and sustainability was touched on in an explicitly and/or implicit manner. While the two outcome spaces seem to converge toward a common point and some relationships and interdependencies between the two terms start to emerge, the full extent of these does not crystallise. During one class session the relationships between ecological justice, social justice, and sustainable design were discussed. In observation notes from that session three themes were recorded: conflicting aims, e.g., carbon captioning and developing countries' rights to increase their emissions or not; the idea of changing people's underlying values, social justice lead to more respect for nature; and not seeing any connection. However, this is not an exhaustive list. One interviewee referred to the reading that sparked this discussion.

> **RS8:** [One article] was interviewing several sustainability people [who] consistently started talking about social justice as being part of the sustainability movement … I entertained the view that they were completely separate … [and] the discussion happened in class, and we started seeing that you can't really have one without the other or that's how I saw it.

Other interviewees expressed similar sentiments or highlighted the relationship between sustainability and social justice in terms of analogous underlying values, components and to some extent aims (e.g., improving society), which can be glimpsed in some of the quotes presented in previous sections. However, the idea of conflicting aims that was observed in the classroom also reoccurred in the interviews, for example:

> **RS10:** They've got the same root problems … it makes sense that if you're working on one you're also working on the other, but at the same time a lot of

> sustainability issues are stemmed from trying to raise the standard of living which is … almost a paradox. When people [aren't] living with such prosperity [but] more modest needs of a lifestyle then there's [less] sustainability issues because they're not consuming more than they need.

However, this mainly seems to be tied to material issues such as standard of living, with other words the distributional dimension of social justice (Gewirtz, 1998). The relational dimension seems easier to align with sustainability, for example, treating other humans and the environment with respect. Due to the collective focus of the analysis method used in this study, no definitive conclusions can be drawn about eventual correlations between conceptions of sustainability and conceptions of social justice, beyond the fact that in a good portion of the quotes used to define the more complex liminal positions for each outcome space, the students talked about social justice and sustainability simultaneously. Also, the increasing emphasis of the social dimension of sustainability logically brings the two terms closer together, which is reflected in the converging outcome spaces. While at the pre-liminal side of the spectrum, it can be speculated that people who have very basic conceptions of each term might be more likely to think that there is no or little relation between the two. This is not to suggest that there is a simple direct correlation between the two terms, but rather, that increased social or critical awareness will facilitate seeing the complex interconnections that do exist. However, it is likely beneficial for students to discuss the relationship between the two terms, as was done in the course studied, as this might help them see connections and serve as a vehicle for their thinking.

The Role of Critical Thinking in the Course

As stated at the beginning of this chapter, one of the course instructor's main ambitions was to help the students understand social power relations in a general sense. He explained a core component of his approach in the following way:

> **SDPC_I:** I try to create a classroom context that asks questions and discusses content in a way that they can get an understanding on their own … and yet still help[s] them see the world from different angles.

Thus, in a general sense the course was an exercise in critical thinking and broadening of horizons. The students' abilities to think critically are reflected in the two outcome spaces above, and are especially apparent, for example, in the liminal position of taking a holistic perspective to sustainability. Some students spoke about critical thinking and the learning process in the course outside of the contexts of sustainability and social justice. Here is a selection of quotes:

> **RS4:** I think the most obvious difference with STS classes in general and my other classes is [that] my other classes either give a lecture and then just expect you to take notes and just to be fed information and to some extent you might critically analyse it, but for the most part just take it in, understand it, memorise it, and then this class it's like you're not memorising anything, you're just trying to understand … things you already know to a higher level.

This student focused on how this class, and other STS classes, emphasises a different kind of thinking than the student's other classes. The next student succinctly summarised what he perceived to be a core impact of the course.

> **RS8:** I think … opening up world views is what this course serves and I think that's why a lot of people would benefit from taking it.

Another student reflected upon what critical thinking entails, emphasised the importance of seeing connections and relationships, and then highlighted its significance for sustainability.

> **RS10:** It's also about I would say promoting critical thinking and problem solving … Definitely looking at when you have a situation it's pretty easy to identify who's involved, but then critical thinking you're thinking about okay so you have who's involved, what else are they involved in and how does that contribute back to what is going on in the particular situation … one of the key things through the course was really taking the issues and finding the connections and relationships between them so that you have an understanding of what's really going on. It's easy to look at one part of it without looking at the whole system, but it's just not what sustainability is about.

Yet another student spoke about how his individual case study prompted several questions about practices in contemporary society and suggested how one needs to approach questions like these.

> **RS9:** [T]he class made me question a lot more of these things, so why have these consumer based problems started in the first place? Why did we just mass produce all these harmful chemicals without even testing them and understanding the implications and things like that, like those and being able to question that is … Understanding that there's differences between things, the way people do things and use things, and the bigger encompassment of that so the industries that you work in, the governments that you're under, the

> worldly social class even that you work in. Having those understandings, those questions, breaking it down in that way…

This last student commented on how the course had encouraged him to take both a broader and deeper view to things and issues related to sustainability and even life in general and emphasised the importance of understanding the underlying context.

> **RS6:** I think it's just a realisation that nothing's ever cut and dry and there's always conflicting viewpoints, conflicting motives, there's ulterior motives to any sort of policy change, technology growth, and that you can't force people to do anything. You need to understand why things are happening, how things are interlinked, and just in general not even just in sustainability, but just in life in general. The course has given me a broader view that we need to be more well rounded to make an educated opinion, and that's something I thought I knew, I always tried to have a well balanced opinion. I always said that the only stupid argument or point of view was an uneducated one, you need to understand both sides of the argument, and I guess I lost sight of that before I took the course because I was always so solar panels and alternative energies, just use them it's plain and simple, but it's not so. You really need to understand.

All in all, the quotes above highlight the students' perceptions of the importance of critical thinking in the course both in relation to sustainability and in a more general sense. In his interview, the course instructor commented that in most cases the students had not achieved the full extent of the kind of thinking he desired for them to achieve, but that they had taken the first important steps.

SDPC_I: Yeah, I'm not quite sure I see the shift to thinking in terms of distribution of power. I don't quite see that. What I do see and I think it's a … a prerequisite, a necessary first step is getting away from very simplistic solutions that impose one highly rationalised solution like we need all cars to be hybrid cars. We need to stop burning coal … they're very sort of singular highly reductive unfeasible solution approaches which they often come in, especially students with an interest in environmentalism, so many of them come in sort of really thinking that the answers are clear, that we just need to do all these things, and people need to suck it up, and actually having them step back from that and say oh there are a lot of, there are a lot of questions and a lot of these solutions involve imposing things on people, and who gets imposed on, and who gets screwed?

I: So understanding that there's complexity rather than just…

SDPC_I: Yeah. So that is something I really think I'm seeing. I see it actually very strongly and that's something I'm very happy about as an instructor, that they're starting to first of all understand it, but second of all start to talk about the multifaceted nature … The point is the student is articulating complex inter-relationships … And for me that's the first step toward understanding.

Concluding Summary and Reflections

In this chapter the findings from the study of the course *Sustainable Design Politics and Culture* were reported and discussed. As this course focused on sustainable design rather than social justice, two separate outcome spaces were constructed—one for sustainability and one for social justice. While the outcome space for sustainability emerged more clearly than the one for social justice, both outcome spaces displayed increasing trends in social awareness and emphasis. In addition, some of the students definitively saw interconnections between the two terms, but since the course did not explore these relationships in any great detail only general observations could be made. Furthermore, the study highlighted that the course instructor's ambition to encourage the students to develop their critical thinking skills was reflected in the students' perceptions of the course.

Overall, the findings of the study suggest that the course was successful in encouraging students to think critically about and broaden their conceptions of sustainability. However, while varying degrees of awareness of social justice were present among the students, it is unclear how the course contributed to this awareness. For example, RPI has a strong STS programme and some of the students in the class had taken additional STS courses with one of them doing a dual degree and this is likely to have contributed to their collective awareness of social justice.

On the other hand, according to Freire (1970) becoming aware is the first step to be able to engage with social justice in a constructive way, and the course seems to be successful in engaging students in the type of critical thinking needed for making awareness possible. However, it appears that if one wishes for one's students to have more articulated ideas about social justice and/or its links to sustainability or sustainable design then one needs to address this in a more explicit manner than was done in the course studied.

Chapter 6

Exploration of Social Justice in an "Ethics" Classroom

Is engineering a moral profession? Florman (1976) believes it is, but expresses at the same time scepticism toward imposing more ethics and responsibility onto engineers partly due to the difficulty of collectively agree on what is morally right. If Florman is right there is no need to proceed further, but there are many scholars who in turn are sceptical of Florman's position. In this chapter an inquiry of to what extent and in what ways a course clothed in the language of engineering ethics (though with a continued stress on critical thinking) expands students' understanding of social justice and ability to think critically is discussed.

According to Catalano (2006) as well as Johnston et al. (2000), one thing that differentiates professionals from non-professionals, is that professionals claim to be guided by certain ethical standards, which are often represented by a code of ethics or conduct. However, there are those like Zussman (in Riley, 2008c) who argue that engineering does not fit this criteria well:

> The technical rationality that is the engineer's stock-in-trade requires the calculation of means for the realization of given ends. But it requires no broad insight into those ends or their consequences. Engineers are aware of, are trained to be aware of, these limitations; insofar as they do consider ends, they cease to act as engineers. (p. 110)

According to Riley, the core in Zussman's argument is that engineers with time have become embedded in (industrial) organisations and consequently have lost much of the professional autonomy they once enjoyed. She concludes that:

> Autonomy and the ability to make independent ethical choices is an essential element of what defines professions in sociological terms. If engineers do not exercise these choices individually and collectively, we may cease to be a profession in at least one important sense. (p. 110)

Despite objections such as Zussman's, engineering scholars, such as Catalano (2006), see a code of ethics as part of the modern definition of engineering:

> Today engineering is seen as a profession which refers specifically to fields that require extensive study and mastery of specialized knowledge and a voluntary and abiding commitment to a code of conduct which prescribes ethical behavior. (p. 13)

Fleischmann (2006), in turn, worries about what she perceives of as diminishing roles for shared values and codes in contemporary society and how this might impact future engineering practice.

> An honor code involves a shared set of values. While the general culture 40 years ago still supported the idea of living under a shared set of values, the general culture today does not support such an idea. ... While we, as practicing engineers, see ethics as a foundation that informs and guides all of engineering practice, and while we accept professional codes of ethics as personally binding, the current culture does not prepare our students to accept the codes in the same way. Because of this cultural shift, what is at risk is nothing less than the ethical practice of engineering in the future. (p. 382)

For Fleischmann, the idea of an honour code is central and she concludes her argument by saying: "[O]nly when students embrace the idea of an honor concept as a way of life and allow their educational experiences to transform their sense of themselves—is our educational purpose achieved" (p. 389). However, there are those who are sceptical to the idea of this kind of "universal" ethic, for example, Ahmed (1998), who writes for a feminist perspective, argues:

> [Carol] Gilligan's work [*In a Different Voice*] suggests that the idea of a universal moral theory neglects the process of gender differentiation and, consequently, the located and embodied nature of subjectivity.
>
> A feminist critique of universalism may begin with a critique of the subject of universal ethical theory. Such a subject or "the ideal observer" is masculine, rational and disembodied. The ideal observer is *abstracted* from the contingencies of the social, including the bodily realm, in order to fulfil the criteria of universality, which involves treating *like situations alike*. As Lyanne Arnault argues, such abstractions are impossible, as people's social identity or location necessarily affects their understanding of the world, and hence any evaluative procedure (Arnault 1990: 195). "Moral agents" are socially constructed, embodied members of historically shifting groups. (p. 52)

Herkert (2005), on the other hand, is critical of the fact that "[m]ost research and teaching in engineering ethics has had a 'micro' focus" (p. 374). He uses the term *microethics* to refer to individual engineers' ethical decision making. He then contrasts this with *macroethics,* which concerns broader issues such as social responsibility and societal decisions about technology, and argues for the need to include this type of ethics in engineering education. This lack of macro focus might be a partial reason why Catalano (2006), when reviewing many of the current engineering codes of ethics in the United States, found them lacking in areas relevant to social justice, such as impact on poverty reduction or enhancement. Riley (2008) takes this argument further:

> Engineers advocating for social justice must be able to stand outside the profession and take a critical look at what engineers do. It enables us to ask key questions: *for whom* is engineering done, who wins and who loses by the actions of engineers, what work is considered engineering, and what values underlie the drawing of these professional boundaries. (p. 110)

The course reported on in this chapter is framed within this critical macro perspective on engineering ethics.

This chapter is broken down in the following way: First, the course context and scope, the role of social justice, and the research approach deployed are described. Then, the findings of the study are presented as an outcome space for social justice and observations about the role of critical thinking in the course. The chapter concludes with a summary and some reflections.

The Course "Science, Technology, and Ethics" and Smith College

The course *Science, Technology, and Ethics* (STE) was created and first taught in 2007 by Donna Riley of Smith College in Northampton, Massachusetts. Smith is a female liberal arts college (female students, some male faculty). The Picker Engineering Program started in 2000 and is "the first and only accredited engineering program in the nation just for women" ("Picker Engineering Program History & Accreditation," n.d.). Students at Smith are required to choose a Major subject, but must also take at least half of their courses outside of that area. This is intended to give them both depth and breadth. Students are encouraged to pick at least one course from each of the following seven fields: literature, historical studies, social studies, natural science, mathematics and analytic philosophy, the arts, and a foreign language. Smith does not offer different engineering programmes, but a general major that allows the students to choose their own concentrations. A completed programme meets the criteria for an accredited engineering programme as specified by the Accreditation Board for Engineering and Technology. Engineering students at Smith are required to fulfil a Liberal Arts Breadth requirement either by completing a course in each of the seven areas listed above or a minor or major in a non-science field. In addition, engineering students need to pick three technical electives that are thematically related. The course investigated in this study counts as a technical elective (D. Riley, personal communication, Fall 2008).

The course instructor summarises what the course is about in the following way:

> **STE_I:** My class is about, well the title is Science, Technology, and Ethics so it is broadly about those three topics … but the way that I framed the course is it's not a traditional way of thinking about engineering ethics as professional ethics, it's thinking about what Joe Herkert calls macroethics, which is this larger question of social decision making that has an ethical component to it or maybe profession wide decision making, the ways that a group of engineers might think about something. And as such it needs to be contextualised in Science and Technology Studies. So a lot of what's in the class is literature that deals with questions of how science and society are co-constructed and so on, so that's sort of central. And then it's also about … I organise the class around a film, called "Fast, Cheap, and Out of Control", and the themes in that film revolve around first this question of objectivity in science, which is sort of fundamental to [the students] being able to approach the film and the issues in the course, but also to being able to critique sciences and supposed objectivity.

The topics of the course were arranged into a series of thematic blocks, which appeared in the following order: Questioning Objectivity; Ethics Approaches; Funding and Practice of Science and Technology; Technology and Control; Science and Social Inequality; Technology and Consumerism; Dissent; Feminist Re-visioning; and Engineering, Social Justice, and Peace. Within each of these themes, the course instructor assigned readings for the students to read and subsequently discuss in class. In my eyes, this was a core mechanic of the course. The class met twice a week and took the form of a seminar, where for about two thirds of the term the students were responsible for leading the discussion in small teams of two or three students. This increase in student autonomy and responsibilities reflects the instructor's commitment to liberative pedagogies. According to Riley (2008d, p. 6), liberative pedagogies (or pedagogies of liberation) emphasise the "sharing of power and shifting authority to students," as well as "hold critical thinking" and "praxis, which can be thought of as reflective action (Freire, 1970)" as "fundamental outcome[s]." This commitment was also reflected in the written assignments of the course, which constituted of: two reflexive pieces on self-directed learning; two action essays, in which the students reflected upon their actions; and one term paper that took the format of a case study on a topic of the students' own choosing. Generally, the work on these assignments was done outside of class, but two class sessions early on focused on the students' individual research.

The Role of Social Justice in the Course

Regarding the role of social justice in the course, the instructor had the following to say during an interview:

> **STE_I:** I mean the what-is-[social justice]-to-me question is much larger than what it is in this class. So I have a history, I've been an activist on a number of issues, some of which intersect with engineering and some of which don't...

> I've always wanted to find a way to connect these parts of my life ... I'm always aware that there are going to be some students out there who are like me, who are somehow in engineering, but have these other interests and maybe want to find a way to make their profession connect with their set of values, so trying to find ways to open that door for students to make some of those connections for themselves. [That's] why the course deals with racism, it's why it deals with gender, it's why it deals with these larger questions about control, that central control, all of those things sort of are windows to that, but fundamentally if they can't get beyond this sort of fundamental epistemology about science, what I'm concerned will happen is that they will just dissociate the two, that their engineering life will be their engineering life and they will think a certain way when they're at work, and then they might continue to do activism outside of work but they'll just pay the bills with one job and then go and do something else after work.

While social justice was not something that was emphasised very strongly in an explicit manner in the class, it did run as an undercurrent throughout the course, and many of the thematic blocks tied directly into or were tangential to it, especially in the latter stages of the course. The above quote shows how the instructor wanted to give students, who have an interest in or values that tie into social justice, an opportunity to make connections between their private lives and their chosen profession. In addition, while adopting social justice as a critical lens to one's practice and profession was not something that was pushed for to any great degree, there was still an invitation in the course to explore that idea and to start thinking along those lines. Thus, it was of interest to explore what conceptions of social justice the students in the class might have.

Study of the Course

Data collection for this study was carried out in the fall of 2008. The course was in its second year and was attended by eight students, who were all in their upper years. Seven of the students were engineering majors and one was an economics major with a minor in engineering. I participated in the class as participant observer twice a week for the majority of the fall term (week two to twelve out of fifteen). In addition to classroom observation, data were collected in the form of student interviews (primary data) and student course assignments (secondary data). Students were invited to take part in interviews about the class and those who took part were asked if they were willing to share their assignments with me. All eight students in the class were interviewed throughout the term (between weeks five and twelve with the majority during weeks nine and ten) and a heterogeneous sample of assignments was collected from six of these students. The interviewees were asked questions such as "What is the course about?" "What do you feel you have learned?" "Has the course had any impact on how you think about your future profession and career and if so how?" and "What do you understand by social justice?" The interviews were audiotaped and transcribed verbatim. The interview transcripts were analysed using a phenomenographic approach. The question "What is social justice?" guided the analysis. Based on how the students talked about social justice or what could be interfered indirectly from other topics, an outcome space was constructed. In addition, quotes referring to critical thinking were also collected and pooled.

Outcome Space for Social Justice

All in all, nine liminal positions (or in some cases contours of positions) related to how the students conceived social justice emerged out of the data. These positions go from a pre-liminal position with little or contradictory understanding of social justice, through increasingly complex understandings, to a position bordering to a post-liminal state where the need to challenge the status quo is highlighted. The different liminal positions are illustrated by the quotes given below and Figure 10 represents a visual summary of the outcome space.

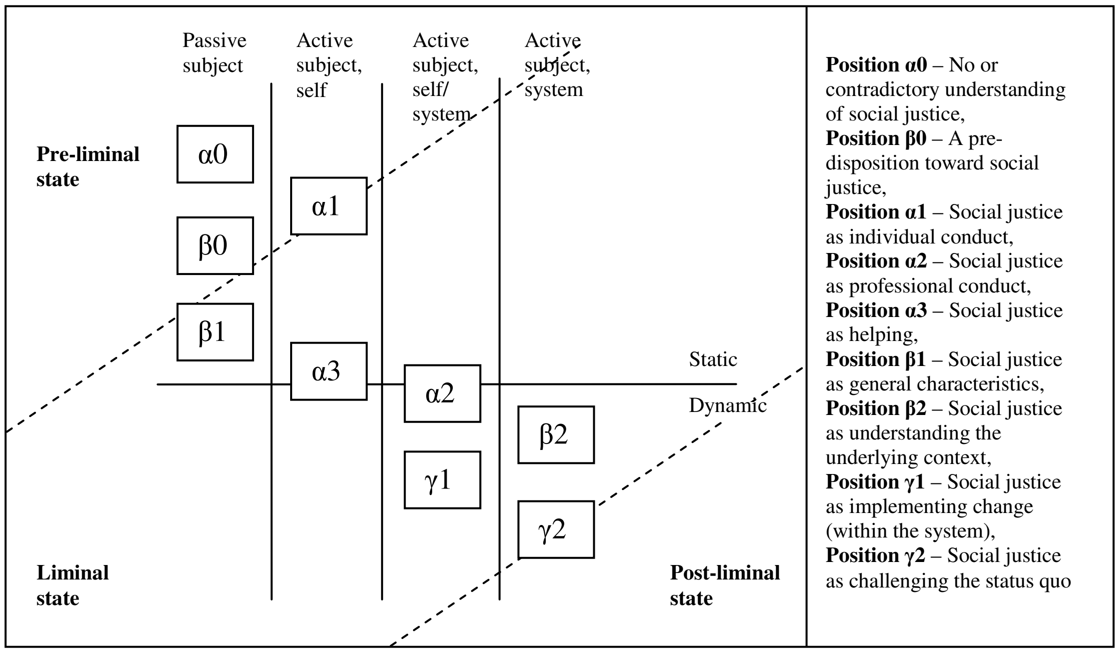

Figure 10: The outcome space for social justice in STE

Position α0 – No or contradictory understanding of social justice

Some students said that they had no clear idea of what social justice would entail or expressed opinions or ideas that were contradictory to engineering and social justice (e.g., the "logic" of an unequal world or that engineers maybe just should do their job without considering consequences).

> **I:** If I say social justice what does that mean to you?
>
> **SS8:** It doesn't mean really much to me right now.

SS3: I feel like the order of the world is to be unjust and unequal … Because you need opposites I guess and if we were all the same … I guess I've never known everything to be the same.

I: So it's basically you say a contradiction with what you think social justice is?

SS3: Yeah.

I: How can engineers work for promoting social justice? Can they do that?

SS3: I think the way that engineers can promote social justice is being … try to be unbiased … Sometimes I feel like engineers should be a profession where you just go to them with the problems and they'll solve it for you, but not have to think about whether the solution that you just gave out to your client will impact the world in a negative way.

This is a distinct pre-liminal position where central characteristics of social justice yet have to come into view. There is no clear focus or subjects.

Position β0 – A pre-disposition toward social justice

Some students expressed sentiments that did not directly relate to social justice, but that can be said to indicate a pre-disposition toward social justice. This included general statements about improving, helping, being ethical, and the greater good.

I: What do you consider to be the right reasons for doing engineering?

SS6: For doing engineering? Just that to help the world improve in a way … well initially I thought about becoming an engineer because I was good in math and science, and so I mean I didn't really know much about it, and now it's more like developing, and all engineers don't do this, but sort of developing new ideas, new products, new medicines, or new things that can help the human population.

I: So what is an ethical engineer or an ethical economist?

SS1: I think it goes back to the ethics approaches, right? How do you determine what's right and what's wrong? I have to use the word responsible again … [an] altruistic person, someone ethical can't be selfish, right? Or you could be selfish, but it all goes back to what is the purpose of doing what you're doing, and it should be something like utilitarian, something to benefit everyone.

SS2: Well, I guess as long as the engineers keep the perspective of doing things sort of it helps the greater good and it isn't completely self motivated I think in that sense it's okay that they have that much control over things, but then I don't know, I guess you just have to have like a check and balance system to make sure that things don't go totally…

Central to this position is a pre-disposition toward social justice and it can be imagined that a vague outline of the social justice threshold can be extrapolated. Thus, this position can be said to exist in a border region between the pre-liminal and liminal states. There is still no clear (specific) focus and subjects are passive.

Position α1 – Social justice as individual conduct

Central to this position is that the students focused on their own personal behaviour or conduct and emphasised the need for being responsible or not intentionally harming others.

> **SS6:** Well it's more self reflection and what I picture myself doing. I want to make sure that I'm doing it for the right reason, and I want to make sure that I don't discriminate against people or … I always try not to, even though you sort of have that mentally you might unintentionally discriminate against some people.

> **SS3:** I think in general as human beings we should all try to be selfless and not just worry about our own things … because it's all about connections, I think it's all about connections, because I mean you could be a hermit, but it's how you interact with people, and you should try to seek the best in people and try to help them the best, and you should put forth your best. So in that sense I guess engineers shouldn't create something that they think is an unnecessary evil. I mean some people, some engineers might have a problem with developing like military technology, then maybe military technology is not for that engineer but some other aspect of engineering is.

This is a fairly simple (that is, not complex) pre-liminal position bordering to the liminal state. The focus is on the self (active subject) and can be said to tie into the relational dimension of social justice (Gewirtz, 1998) in a practical and personal way.

Position α2 – Social justice as professional conduct

Quite a few of the students in the class emphasised the importance (for engineers) to consider the wider scope and/or implications of one's (professional) actions. This was either explicitly linked to social justice or the connection could be indirectly inferred. Also, there is a dimension of consulting a wider group of people or community when carrying out a (engineering) project or similar activity.

I: To be a responsible engineer, what would that mean?

SS1: I think it means a conscious engineer who's aware of his projects, his research. You have to think about how you are affecting society, the environmental impact, just being conscientious about what projects you take on. For example, I think we mentioned it in class, the Ford engineer for the Pinto they decided oh how much is a human life worth, well what would a human life cost you, it's not worth it. That would not be a very socially responsible thing to do. And also maybe if you have a high tech project, maybe in a car, how fast it goes, horsepower isn't the most important [thing], maybe safety, emissions, fuel usage, mileage, that type of thing.

I: What do you think about engineers solving problems and what's engineering problem solving about?

SS2: Well, I guess it's meeting specific user needs, but then while you're trying to meet a certain population's requirements or needs or whatever, you actually keep ... it's going back to the same idea of keeping the rest of the community in perspective also.

I: Do you feel that [the instructor's] course relates in any way to social justice?

SS4: Yeah, I think so. The things that we've been talking about are about taking into account more than just the design and how much it's going to cost without looking at what are you doing to the environment and does your technology have politics, and who is it disadvantaging?

I: Can engineers actively work in social justice?

SS7: Yes.

I: Give me an example, please.

SS7: I mean developing a technology for a specific group of people to help their situation, but making sure to work with them to understand how it's actually going to benefit them and what impacts it would have.

This is a distinctly liminal position that can be seen as a broadening of the scope in Position α1, with a shift from one's treatment of others to the impact of one's actions on others. Here, clearly identified active subjects are placed into relation with others in a more systemic way.

Position α3 – Social justice as helping

At this position, students focused on social justice as the act of helping or providing help in response to a perceived need, e.g., to build infrastructure or construct cook stoves in developing countries. Generally, students did not indicate a clear consultation process with "local" clients.

I: And what would it mean to do social just engineering?

SS2: Well I guess … if it's a developing country I guess engineers who are involved in … building infrastructure and things like that.

SS6: Regular engineers can be part of social … well like the cook stove people, those engineers, they're part of social justice, they understand that the cook stoves … that some of these families have is hurting them so they feel a need to correct it by creating a new one.

I: Okay, and are they creating them with input from the locals or are they designing them over here and then just go over and…?

SS6: They've talked to the people I think.

This is another liminal position that can be seen as a branching from Position α1, but here the focus is on actively helping others who have a perceived need. However, the focus is much narrower than in Position α2, and the wider context surrounding the "need or problem" is not emphasised. Clearly expressed active subjects are part of the position.

Position β1 – Social justice as general characteristics

Another well represented position among the students was talking about social justice as something more general or intangible in nature, often using terms such as *equality*, *access*, or *fairness.*

I: What does [the term social justice] mean to you?

SS5: The thing is often I think in binaries, so I think justice is whether if it's fair or not fair. So social justice is whether or not society is fair or not fair.

I: Okay for whom?

SS5: For the people. I guess you can't even think just for the people you have to think about the environment as a whole ... Like the whole ecosystem … I mean we have to think about nature as well.

I: Do you feel that social justice would be mainly about redistribution of goods or are there other parts that are important?

SS2: Well, I guess going back to the gender issue itself. If there was more social justice, I guess if there was more balance even in the engineering field itself, it's so dominated by men, and I think if the system was more socially just it would be easier for women to enter the field and things like that yeah.

SS3: Some things with engineering such as gadgets like the IPod or stuff gives us a certain perspective of happiness and what we need or don't need … I don't think that it's just because some people don't need such improvements, like technological improvements. And if it was to look socially just or like fair all across the board … have a balance of both but not some people are overly developed and some are not developed at all.

I: So if I say this term social justice, what does that mean to you?

SS4: Equality across class and race and things like that.

I: Okay, so how would society look if it was more socially just?

SS4: I guess people wouldn't be starving or exploited in the workplace.

This is a liminal position where the subject self takes a back seat, and in contrast to the α-positions here the subjects do not take possession of social justice, but treat it to some extent as something that has an independent existence outside human relations. Both distributional and relational dimensions of social justice are acknowledged, but mainly in general terms.

Position β2 – Social justice as understanding the underlying context

Central to this position is an emphasis on understanding the underlying context in order to work for social justice.

SS7: I mean I think that ... in order to work for social justice or at the very least make sure you're not working against it, you have to be aware of what's

> going on and what you're doing, and so you have to apply critical thinking to your actions or the actions of others too.
>
> **I:** Can you think of anything in this course that has linked the two?
>
> **SS7:** Um …
>
> **I:** I mean it can be a reading; it can be something said in class.
>
> **SS7:** Off the top of my head not really.
>
> **I:** Okay, so the link is something that you've drawn from all your experience?
>
> **SS7:** I think yeah.

This is a fairly advanced liminal position which emphasises awareness, but also active subjects. This awareness goes much deeper and is more critical in nature than the one represented in Position α2. As indicated by the quote above this position represents a dimension of critical variation in how social justice is conceptualised, which is present in the data, but which cannot be directly attributed to the course.

Position γ1 – Social justice as implementing change (within the system)

Central to this position is a desire to implement positive change while still working within the current system.

> **SS3:** Well something that I'm interested in is actually going to Vietnam and helping them sanitise their water and more specifically the smog and pollution from the bikes that they always use ... I want to make it an issue that people's health are deteriorating or they're not as great as they could be, and I want to be able to implement change, like change the policy in the sense that alright the Government should say that these companies shouldn't be producing "x" amount of emissions.

This is another fairly advanced liminal position that to some extent combines elements of Position α1 (helping) and Position α2 (wider scope). This position involves active subjects engaged in addressing systemic issues.

Position γ2 – Social justice as challenging the status quo

Central to this position is changing the system or challenging the status quo. Social justice (or socially just engineering) is not possible within the current system or part of working for social justice involves changing the system.

> **SS2:** I guess one example I'm thinking of is medicines that are available in developed countries versus … some things are not available in developing countries. So in that sense I think if there was a better way to engineer or whatever I guess I think it could serve a bigger purpose than just the people who can afford medicines, for example.
>
> **I:** Okay so what are you talking about there? Are you talking about how things are made or are you talking about distribution or?
>
> **SS2:** I think the whole system, the whole process that's in place, if everybody could like help towards changing it.
>
> **I:** Okay so engineers …
>
> **SS2:** And engineers are a big player in that field because they're so involved in those aspects, do I make sense?
>
> **I:** Yeah I think yeah it's like they're a part of the process sort of.
>
> **SS2:** Yeah and they can act as like the catalyst to help to get other people on board yeah.

This is a position that boarders to a post-liminal state, as social justice fundamentally is about changing an unjust status quo (Marullo & Edwards, 2000). Here, active subjects are involved in a dynamic process to change the current system. To some extent the advanced awareness in Position β2 is combined with the action form Position γ1.

Summary of the social justice outcome space

Nine liminal positions (or in some cases contours of positions) related to how students in the course conceived social justice emerged out of the data. These positions correspond to an increasingly complex understanding of social justice and range from a contradictory pre-liminal position to bordering to a post-liminal state where the need to challenge the status quo is highlighted. The most prominent referential and structural shifts in the students' ways of experiencing social justice include a shift from passive to active subjects and shifts from no clearly expressed focus to focus on the subjective self to focus on more systemic issues. There was also a shift from talking about social justice as something static to something more dynamic.

The role of Critical Thinking in the Course

Critical thinking was at the centre of this course as reflected in a number of its objectives. For example, to receive a passing grade students should be able to "[t]hink critically about science, technology, and ethics, identifying and analyzing a variety of ethics problems" and "[e]xplain the complex relationships among science, technology, and ethics in current social contexts, and how these contexts inform and influence social choices about science, technology, and ethics" (Riley, 2008a). In an interview, the instructor expanded on the rationale behind this and the basics of the approach she used to help students reach these objectives.

> **STE_I:** I start with this critique of science and engineering and the sort of epistemologies that underlie it just to be able to recognise that the way engineering is taught has a name in philosophy, it's a deliberate approach and there are other ways of approaching it. To understand that is to be able to step outside of it and say okay this isn't just how things are, I can actually see a power structure here now and it's something that I could challenge ... it is a raising of awareness if you will, but it's an awareness of the power structures, of the structure of knowledge, of the fact that what's in their textbook isn't necessarily the end all be all of what a subject is, and it's not the only way of presenting the material, and it's not ... not necessarily true.
>
> **I:** So basically a deconstruction of engineering?
>
> **STE_I:** Yeah.

Later in the interview, the instructor commented on how she encouraged the students to take ownership of their own learning, and in doing so to start seeing new possibilities or different ways of doing things relevant for their own lives and future careers.

> **STE_I:** I want them to take ownership, that's why I want them to be actively thinking about these structures and how could things be different, and do they just have to obey the boss, do they just have to listen to the professor? No, they actually could come into a classroom and it could be very different ... So to give them that sense that there might actually be different expectations or different structures is important because they might, when they get in a certain hierarchy start to think about well do the meetings have to be run this way, do I have to just listen to my boss drone on...

Further on in the interview, the instructor gave a concrete example of a situation in which she hoped the course would be of use for the students.

> **STE_I:** There's always this question about how involved are they going to be in military projects, right? And for all of these students they have to come down in a different place on that, and if they just think about it I will be happy, because we have so many students that go in now without thinking about it and it pays the bills...

Now, while the course instructor placed critical thinking at the centre of the course, how did the students perceive this and what impact did they feel the course had on their thinking? Here is a selection of quotes illustrating student perspectives:

> **I:** What do you think [the] course is about?
>
> **SS7:** I feel it's really an exercise in critical thinking. I guess just identifying all of the possible issues that are at play within a particular bigger issue and learning to I guess have the tools to look at things more critically and not accept them for face value … I guess just really looking at information, challenging the assumptions that are made with it and understanding, I guess being critical of it … I think that I've always been kind of prone to think along those lines anyway, but [the course] also has exposed me to a lot of different sources or issues or something that I hadn't really realised were out there … in learning more facts that I hadn't considered before it kind of opens me up to the possibility of there being more things I hadn't considered before, so it kind of pushes my boundaries in terms of how I think about things.

This student expressed a position similar to that of the course instructor, and while she felt that she already was prone to think along similar lines, she thought that the course had encouraged her to develop her critical thinking skills further. In contrast, the next student perceived a shift in her thinking due to the course.

> **SS5:** I find the class, the topics in the class that we discuss have forced me to look at things differently, like with a different eye … I'll think about it more and ponder a little more and I'll figure out okay maybe there is more to this. What are the negatives of this? … When an engineer and an architect built this structure did they consider the implications of what they've done and how it affects latter generations and things like that?
>
> **I:** Before the course you didn't think that way?
>
> **SS5:** Not really no.

Similarly, yet another student pointed out how the course encouraged thinking in terms of further deconstruction of an issue, preferably from multiple points of view.

> **SS6:** Another thing [that I will walk away with from the course] is … how to think of different situations from different points of views, and I consider myself a pretty open minded person, like I have the ability to do that, but … there's always more layers that you can look at and from.

However, this type of questioning is not always easy, but rather challenging, especially when turned toward one's own actions or life, as SS7 commented.

> **I:** Have you learnt more about your future career and what it means to be an engineer?

> **SS7:** I think that the immediate effects that I've seen of it are kind of small [and] could pretty much be summed up in just discomfort. [Because in] the senior design clinic … ultimately the request for [my] project came from the Department of Homeland Security, and nominally it's a system to help fire fighters navigate in a burning building, but in the back of our minds we kind of have the "what else could this be used for" question that we've just kind of been pushing away, and this class brings issues like that to the forefront ... and I guess that's how I see it affecting me down the road, just the discomfort associated with knowing that I've been told I need to do whatever and being aware of the other issues and trying to figure out how to do deal with that in terms of my career but also in terms of ethically.
>
> **I:** Has the course started that?
>
> **SS7:** I feel I already had the inclination, but it was a lot easier to push it down when I didn't have to directly think about it two times a week.

In addition, SS7 highlights how an ongoing course with a continued emphasis on critical thinking keeps bringing troublesome questions back into focus, when it otherwise would be easier to forget or ignore them. While this was just a small selection of the students' own perceptions of their critical thinking abilities in relation to the course, overall it seems it seems that the course was successful in at least encouraging students to start thinking along these lines. This assessment is also echoed by the course instructor when she reflected back on the course some time after its end.

> **STE_I:** In the end, their final reflections showed a range of personal transformation—some wrote eloquently about how their thinking has changed,

> and things they are doing differently, while others maybe didn't even seem to understand the question. Interestingly, this did not necessarily relate to engagement or class performance. So that's an important lesson I think… that other parts of students' lives might impinge on their day to day performance, but the course is still having an impact on them. They may not learn the content as well if they don't do the reading, but if their conceptual framework or outlook toward science, technology and ethics (or engineering and social justice) is changed, that is far more valuable. And most did seem to get the "big picture" points.

Concluding Summary and Reflections

While STE counts as an engineering ethics course it differs from most other courses with this classification as it emphasises a more societal and communal macro perspective rather than the more common individual micro perspective. The distinction between macro and micro perspectives serves to situate the course in a wider academic context. In practice, in the classroom little time was spent on philosophical definitions, but rather on exposing the students to a series of thematic blocks which problematised the role of engineers and scientists in varying contexts. The main ambition of the course instructor was to help the students begin to understand the socially constructed nature of science and technology by encouraging them to develop their ability to think critically.

Social justice runs as a strong undercurrent through a number of course elements, but the term was rarely, if ever, used explicitly in the classroom during the time I observed the class. This might be one reason for why some students spoke of social justice in quite general terms when asked what it meant to them. Despite this vagueness, nine liminal positions emerged from the data. While these positions can be arranged in accordance with increasingly complex understanding of social justice going from a pre-liminal state to bordering on a post-liminal state, it is somewhat unclear exactly how the course contributed to the positions in this outcome space. The position corresponding to seeing social justice as professional conduct and considering the wider impact of one's actions fits well with macro perspective of the course. However, eventual relationships between the other liminal positions and the course are less clear. Here it is important to point out that the interviews were concluded before the last thematic blocks (Dissent; Feminist Re-visioning; and Engineering, Social Justice, and Peace) of the course, which had quite apparent ties to social justice. In addition, according to the course instructor, Smith College tends to be a more liberal place than other more traditional universities. This and the fact that students are required to pursue courses outside their discipline might have played some role in the liminal positions that emerged out of the data. On the other hand, the instructor also commented that engineers tend to be more conservative than other students and that she felt that the majority of the students in the class were fairly typical engineering students.

To conclude, it is quite likely that the course had some impact on how students thought about social justice. One thing is clear though, the central role of critical thinking in the course was reflected in the students' perspectives on the course, with a few of them feeling that the course had encouraged them to engage in this kind of thinking and reflection. Furthermore, ability for critical thinking is important for engaging with social justice in a constructive manner and thus, the course is likely to help students navigating the liminal space of social justice to some degree.

Chapter 7

Exploration of Key Pedagogical Characteristics for Encouraging Students to Develop their Critical Thinking and Approach Social Justice

It is one thing to argue for the need for engineering education guided by the ideals of social justice but how to actually do it in practice is another. The approach used to study student learning in three different courses with connections to social justice was described within the methodology and method sections of Chapter 3, the “how” and “what” of learning in these classes were reported on in Chapters 4-6, and the pedagogical implications of those studies are presented in this chapter. First, to situate this discussion, a range of perspectives from different education scholars are introduced. Prosser and Trigwell (1999) provide a starting point by arguing that good teaching in higher education involves a continuous awareness

- of students’ present learning situations;
- of the contextually dependent nature of teaching;
- of students’ perceptions of teaching technologies (including information technology) used in teaching;
- of the student diversity (including cultural diversity) in classrooms; and
- of the need to continually evaluate and improve teaching. (p. 166)

One implication of this is to be aware of the different approaches students might take to their learning. Drawing on phenomenographic research, Booth (2004) discusses two such approaches:

> [A] *surface approach* in which the focus is on the task as given, on the sign, on doing what the task seems to call for in the educational situation; and a

> *deep approach* with focus on the meaning embedded in the task, that which is signified, on relating the task to prior knowledge and experience. These approaches are not characteristics of individual students but are, rather, the result of the student's interaction with the task in the learning context in which it is experienced. Thus, a student might well (and without choosing) take a deep approach in a task that is of intrinsic interest, where it is felt that the teacher will give significant feedback, and where the context invites engagement with the subject matter, And the same student might take a surface approach in a context that is uncertain, where the task seems arbitrary or busywork, where the study programme is crowded and time is short. (p. 17)

For students to be successful in grasping all the complexities surrounding social justice they likely need to adopt a deep approach to their learning, and thus, teachers should strive to create an learning environment that support this. Mezirow (2000) emphasises the need for this supportive learning environment further:

> [L]earning theory must recognize the crucial role of supportive relationships and a supportive environment in making possible a more confident, assured sense of personal efficacy, of having a self—or selves—more capable of becoming critically reflective of one's habitual and sometimes cherished assumptions, and having the self-confidence to take action on reflective insights. (p. 25)

A *supportive* learning environment is not necessarily the same as a *safe* learning environment. hooks (1994), for example, comments that many professors feel that a classroom should be a "safe" place, but that this leaves little room for the students' emotions and passions and that those who come from marginalised groups rarely feel safe in a conventional North American classroom. Ellsworth (1989) points out that there are things each of us never can know and thus, there cannot be a universal approach to student empowerment, but rather, teachers need to be attentive to who is in their classrooms and recognise “differences as ‘different strengths’ and as ‘forces for change’” (p. 319). Similarly, hooks (1994) argues for the need to “build community in order to create a climate of openness and intellectual rigor” and “that one way to build community in the classroom is to recognize the value of each individual voice” (p. 40).

Cousin (2008) observes that “threshold concept theorists have suggested that we need to convey to learners that discomfort and uncertainty are normal dimensions of learning” (p. 263) and continues to suggest that “the idea of threshold concept mastery is tied into seeing unsafety as an unavoidable part of the learner’s journey and the concept of liminal states offers an explanatory framework for this journey, which links up learning with identity processes” (pp. 263-264). Palmer (1998) reflects on this potential learner discomfort in a wider context:

> Good education may leave students deeply dissatisfied, at least for a while. I do not mean the dissatisfaction that comes from teachers who are inaudible, incoherent, or incompetent. But students who have been well served by good teachers may walk away angry—angry that their prejudices have been challenged and their sense of self shaken. This sort of dissatisfaction may be a sign that real education has happened. (p. 94)

The main body of this chapter constitutes an overview of different key pedagogical characteristics of the three courses studied in this dissertation. The chapter is concluded with a summary and some reflections.

Key Pedagogical Characteristics of the Three Courses Studied

By drawing on students' perceptions of their course (especially related to the questions "What helped your learning" and "What aspects of the course did you find useful?"), the teachers' perspectives on the choices they made in designing and teaching their courses, and observation of actual classroom dynamics in each of the three courses, a number of key pedagogical characteristics could be identified emerging from the three courses. The most prominent of these were the opportunities and challenges of: an interdisciplinary classroom, a seminar-based classroom, the role of the teacher as facilitator and indirect guide, student autonomy and responsibility, and constructive course assignments. These key characteristics are further discussed below, together with additional pedagogical aspects of the three courses, and are in most cases illustrated by quotes from students and instructors. In addition, an example is given of how the research reported on in this dissertation contributed to practice in one of the courses. Here it is important to acknowledge that concerns might rise about the fact that much of the data is drawn from the perspective of students. For example, the course instructor of SDPC had the following to say regarding this:

> **SDPC_I:** You have to sort out whose perspectives to prioritise ... from an instructor's perspective my experience is that students don't have a very good sense of why a class is working or why a class isn't working.

Adawi and Linder (2005), on the other hand argue that:

> The pedagogical value of phenomenographic research lies in its potential to improve teaching and learning in [a subject] by taking the *learner's perspective* and focusing on the *essential variation* in the ways that key concepts, principles and phenomena may be thought about. (p. 6)

While the research approach used in the study discussed in this chapter combined elements from phenomenography and threshold concept theory, and thus differs from conventional phenomenographic approaches, the newly adapted and merged approach taken in the current work, builds on this essence of variation within and between conceptions and yet takes it further by considering the variation through the liminal space of these conceptions.

Some opportunities and challenges of an interdisciplinary classroom

Each of the three classes studied had a different student mix. *Science, Technology, and Ethics* (STE) consisted exclusively of students with ties to engineering. *Sustainable Design Politics and Culture* (SDPC) was made up of students from mainly technical disciplines, including engineers, architects, design majors, and one or two science and IT majors. *Engineering and Social Justice* (E&SJ) had the most radical diversity combining engineers with students from social sciences such as sociology and developmental studies. In addition this class was co-taught between an engineering professor and a social science professor, while the other classes were taught by one professor each. In E&SJ the idea with bringing students from such different disciplines as engineering, sociology and developmental studies was that they would learn from interacting with each other. For most students it was a novel experience to share a classroom with people influenced by the thinking of a radically different discipline and this encouraged them to expand their horizons. Here is what two students had to say:

> **QS14:** I loved that there was a mix … I would love to see more interaction between engineers and sociologists, but again I wouldn't want that sort of thing imposed … but I wanted more of it to happen just because it was so interesting. When we were working with QS8 … she was the only non-

engineer in the group and … she just thought of things very different than we do and I really liked that and would have liked to see more of that.

> **QSR12:** The most valuable aspect of the course was the opportunity to interact with other students coming from very different backgrounds, especially the engineering students. I found the in-class discussions very interesting, especially as students with different perspectives tried to understand each other and communicate their interpretations of subject matter. … the opportunity to work together and question our assumptions of what we think we know.

In a similar vein, the professor of STE commented on the lack of students shaped by radically different thinking than engineering.

> **STE_I:** I still hope that someday I'm going to get somebody from the other side of campus, and then that will raise the level so much … if I get a philosopher in the class or if I get … a major from Women's Studies it'll change the whole thing, their perspective, it'll also change the group dynamics so it could be good or bad, but depending on who's in there it could really help.

Most of the interviewed students in SDPC thought the interdisciplinarity of the class, albeit narrower in comparison to E&SJ, beneficial for discussion. However, some students and even the instructor saw difficulties:

> **SDPC_I:** I think it would be easier if they were all the same… Because I think the course content is stretching them outside of their discipline as it is…

> And if we all stretched out in one direction it would be easier than stretching out from multiple directions.

One student commented that a lack of a common ground at the beginning made communication across the disciplines difficult.

> **RS3:** [In another course the instructor] introduced the class as introducing us to the discourse ... so that was really great because it gave us a background of information so we were all on the same level of understanding so we had a ground base for discussion.
>
> **I:** Okay so you sort of miss that here?
>
> **RS3:** It's really frustrating and ... I feel like we're missing that ground level of being able to communicate for the sake of the subject and not the subject in the context of [University].

Based on the discussion above it appears that for engineering students trying to grasp topics as social justice it can be beneficial to be in the same classroom as students from disciplines notably different from their own as this is likely to bring additional new perspectives and broaden the discussion. However, if the class size is very small or students from one discipline are in a significant minority the dynamics of class discussion become very dependent on the personalities of the individual students. For example, the architecture students in SDPC felt a bit marginalised in the engineer dominated class. On the other hand, in the 2008 iteration of the E&SJ class the social science students were in a clear minority, but because a few them had strong personalities, they made their presence felt in the classroom. Then again, they had an ally in the social science professor.

The value and challenges of team teaching

In E&SJ the presence of two instructors from different disciplines helped to facilitate communication over the disciplinary borders, since the engineering professor could act as "interpreter" for social science terms, unfamiliar to the engineering students and vice versa for the sociologist with technical terms.

> **I:** The most fruitful part of what's happening in the classroom?
>
> **QS2:** The discussions definitely, you learn from each other, right? ... I like the fact that [either of the instructors] talks and then opens it up for discussion because then they … also reconsider and ask what they [the other instructor or the students] are saying so anything that wasn't clear cut before is cleared up through the questions that the class brings up.

In addition, the instructors are people with open minded attitudes willing to critique themselves and each other. So the students knew that disagreement was OK as the two instructors could argue with each other and take different positions during discussions. This resulted in that the idea of the existence of a "right" answer was challenged.

> **QS14:** [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 not an answer or right or wrong or ... you could judge it accordingly.

Ideally, the kinds of classes discussed in this chapter should be co-taught between an engineering professor and a professor from another appropriate discipline. However, a potential barrier to this is finding the time for academics who might already have significant teaching commitments to "double up" on one course. However, one potential coping strategy could be to reduce the number classes as there is so much self-teaching (different students teaching one another, reading, project work) so the number of classes with both professors present could be half the usual contact hours, hence, the same work load.

Another important aspect of the team teaching in E&SJ is that both professors marked all submitted assignments so the students always got two sets of feedback detailed and according to the professors this made a big difference in the students' performance. Again, a potential barrier to this is the lack-of-time-argument, but similarly to how the number of classes could be reduced the number of assignments can potentially be cut in half. Well conceived and designed course assignments (as discussed further below) combined with the level of excellent feedback given to the students of E&SJ from two different discipline professors will be a great vehicle for learning.

Some opportunities and challenges of a seminar-based classroom

Freire (1970) made the distinction between what he called banking (passively being told the "right" answers) and problem-posing (actively finding answers through dialogue) education and how the latter is more appropriate for helping learners successfully engage with topics such as those covered in the courses discussed here. These ideas are not necessarily unique to Freire, but in the context of this chapter his ideas are sufficient framing devices. Drawing on this, the three courses were run as seminars focused on active participation and the classrooms were in the case of E&SJ and STE (and sometimes SDPC), set up to facilitate this.

> **I:** What do you think of the course format? The sitting in a ring and mixing up with everyone?

> **QS6:** I think it is good, I don't know how you could better organise a course like this. Everybody get to face each other and see the person that is talking, it is not like the lecture where everybody is facing forward to the front.

> **SS1:** I like the way the classroom is set up also, we're sitting around kind of like talking about it, whereas if you have the standard course setup of everyone sitting in rows starring at the teacher I think the interaction you would have between everyone else wouldn't be as effective and I think [the instructor] is pretty good about getting everyone to talk, even though it's intimidating if you haven't done the reading and she's staring you in the eye.

In addition to a classroom that encourages interaction, a small class size is crucial since it becomes impossible to have a meaningful discussion with too many participants involved. Also, as students are moving into risky territory, it is important to be able to "hold" their fear. This cannot be done in a lecture theatre.

> **QS9:** I am glad I took the course. I think it's an important course and … I wish everyone would take it in engineering but ... then you'd have to go to lecture style of this is "engineering and social justice" and then one wouldn't take it seriously so…

> **QS6:** This is a course that wouldn't be very good if it was a lecture. You need the discussions.

The role of class discussion was spoken about in a positive light by a majority of interviewees from all three classes.

RS2: I think the class discussions are really sort of the most, not helpful, but like the key feature in the course, I think it's the strongest feature in the course.

I: What do you get out from the classroom?

RS2: A lot of just different opinions that I would never have thought of. So the beauty of everyone coming together is that everyone gets to speak and that's why he pushes for the participation because like everyone gets their ideas out.

However, for students who are not used to discussion based courses (such as many engineering students) the switch to this type of classroom might prove an initial challenge.

RS7: The discussion, it was really hard to get used to because I never really had a discussion based course, but it's probably been the best in the end.

I: Okay. So it was sort of a … a bump to get over?

RS7: Yeah.

I: But once you got going you feel that it is a good learning experience?

RS7: Yeah.

However, if discussion is used to drive what happens in the classroom students need to participate to make it work.

SS5: I'm kind of disappointed in the class honestly, because I feel like out of the eight students that are in the class ... only four of us participate in anything. So there's a lack of participation, and I really want to know what other people's ideas are, but they don't speak up and if they do you can't hear them and I just get really frustrated.

While some of the interviewed E&SJ students said that they preferred to listen to their peers debating rather than participating in the discussion themselves, this had less or no impact on the ability of the class to sustain a discussion since class size was larger in comparison to STE. However, this raises questions about who gets to speak and who gets to dominate in the classroom. Drawing on the work of Ellsworth (1989) and hooks (1994) an important aspect to consider is how to create a respectful learning environment where students have the autonomy to explore and engage with the themes of the course through their own agency. The instructors of the three courses generally did not tell the students what to think, but encouraged them to come to their own conclusions through the use of open-ended and probing questions. However, while the instructors knew how to do this respectful, but probing dialogue, the discussion dynamic between the students in the class was not always as smooth or beneficial.

> **QS10:** I feel that opinions are really respected when people put up their hands and they're asked to talk, I feel like everyone is very respectful … but I do find it [discussing with engineers] intimidating just because a lot of people seem to have this very dominant and clear view of how they think things should be … I find it very challenging to construct an argument that is a counter argument in the convincing way, and I find that some people have such a … they made up their minds so clearly.

In addition, some students appeared to find it a bit troublesome when their position or thinking was challenged by probing questions from their peers or the instructors.

> **RS5:** Okay so it's supposed to be a discussion format, but I feel like if I say anything then no matter what I say it just comes off as being stupid, oh you shouldn't have thought that, you should have thought about something a little

> bit more deeply, but it's like it doesn't matter, we're just discussing that. Like if I have a point then I can say it and that's just as valid as what anybody else wants to say.

This particular student followed up on this theme once the course was over:

> **RS5:** I know [that] in our interview I was very frustrated by the class and by [the instructor] in particular. Even if I took the same class again, I still think that I would be bothered by the way it was taught. But, I do think that I was able to take something away from the class. ... I don't know why I had the impression all semester that [the instructor] hated me, because I just don't think that is true. I have had [the instructor] for two classes now, and out of all my professors he is probably the one that I have gotten to work the closest with and been able to get the most personalised feedback from—even if his comments aren't always what I wanted to hear! I think that the personalised feedback is very valuable though.

Role of the course instructor

In a seminar-based course the instructor takes on the role of facilitating discussion (if this role is not ceded to students). In line with Freire's (1970) discussion of problem-posing versus banking education, all three courses strived for a fairly horizontal relationship between professors and students and the instructors most often tried to take a step back and let the students take ownership of the discussion while trying to provoke students' arguments and thoughts one step further when needed.

> **QS1:** [The instructors] are always questioning in terms of what we're handing in and everything ... [e.g.] Is this socially just or just charity? I think that constantly being asked that question is very helpful in terms of defining social justice and now because of that … anything that gets drilled into you, you keep on thinking about it. So it's good.
>
> **I:** So the constant questioning makes you …?
>
> **QS1:** Yeah, sort of routine to think about that in day to day life. There are definitely cases now where I'll be thinking: Wait a second!

This encouraged students to not only state an opinion, but actually try to take a position which is much harder and requires more critical thinking. In line with the discussion above this probing dialogue needs to be carried out in a respectful manner.

> **RS6:** The fact that we call the professor by his first name, it changes the whole dynamic of the course because [you] feel much more comfortable to talk to him in and outside of class, to email him, to participate in class, his teaching style is great where even when you make a comment that isn't correct or not always very intelligent or maybe not always insightful he never, he always brings you up to that level.

From the study of the three classes it can be observed that when helping engineering students grasp topics as social justice and/or develop critical thinking skills it is important to encourage students to take responsibility for their learning and provide a learning environment that allows for this. However, since engineering students are not used to classes carried out in a seminar manner it is important for instructors to provide enough support to help the students cope. While student autonomy is very important for students to develop as independent, critically thinking individuals there needs to be enough structure so the main message of the course is not completely lost. Ideally, this is done through indirect means, such as open-ended questions, that help students develop their conceptual abilities through their own agency rather than the professor trying to tell them how to think.

> **I:** What do you feel has been the most important part of the different aspects of the course?
>
> **RS7:** I think from the discussion ... the way we all talked and just the way [the instructor] leads the course, because he always takes whatever conversation we're having and he steers it, he always like asked the questions to make it bigger.

In addition, E&SJ was taught in what course instructor Richard Day refers to as the "jazz" style of teaching (a fixed structure but which allows creativity to emerge and bloom) which provided the flexibility to adapt aspects of the course to meet the need of the students. One example of this is how the instructors decided in the 2009 class to change the focus of the students' second essay. Rather than writing a critical response to one of the week's readings, the engineers and the social scientists got different assignments. The engineers were asked to do their best at deconstructing some of their own writing or thinking. The social scientists were asked to find viable alternative solutions to current practices while accepting the constraints of engineering and not simply deconstruct and point out flaws and shortcomings as they might be used to doing. Much anxiety could be observed in the classroom about this new assignment, but after more detailed instructions with illustrative examples were sent out the students produced some remarkable essays, as reflected in the excerpts presented in the section on perception shifts of engineering in Chapter 4.

Student autonomy and responsibility

All three courses put a great deal of responsibility on students for their learning. In a seminar-based course students need to keep up with course readings and to develop the desired conceptual tools they need to engage with the material and participate in the classroom discussion. The degree of autonomy students had varied between the courses. In *Engineering and Social Justice* (E&SJ) they got to decide what weekly readings to critically respond to and how to execute group projects they had chosen from a list or generate their own project. In *Science, Technology, and Ethics* (STE) they had to prepare and lead the class discussion two times during the term and choose the topic of their term paper. In *Sustainable Design Politics and Culture* (SDPC) they got to choose a significant portion of their (individual) readings and the topics of their case studies.

Facilitating increased student autonomy for beneficial student learning outcomes requires important skills and understandings on behalf of the teachers and the students. In SDPC, picking their own readings worked well when students could link them to their case studies later in the course, but initially when building a conceptual tool box the freedom created confusion and made class discussion difficult at times.

> **I:** How much freedom should students have to pick readings?
>
> **RS7:** I think the freedom isn't bad. ... [but] it's like we didn't really know what to choose. So we're just bringing in kind of anything and it wasn't always very educated how we picked what we were bringing in. ... I think it was troublesome and I'm confused.
>
> **RS6:** Originally ... all our research updates [and] the readings had to be related to what we were learning in class, the different topics. Once they shifted to now write the research updates about your case study then it became

> an actual research update, then it became more relevant. So now the discussion in class is very helpful because I'm having problems in my paper and I'm able to talk about that with other students.

Here it is worth noting that the challenge this initial confusion posed to the students might very well have paid off later in the course in terms of the students' conceptual abilities, but the teacher needs to be aware and support the feeling of being outside the students comfort zone.

> **SDPC_I:** [U]nderstanding an STS type analysis, a complex systems analysis of sustainability is not trivial … recognising how complex it is especially for engineering students who really are taught from day one that if you're smart enough and you get all the variables you can control the whole system. Like that is the way their education is organised and we are saying no the system too complex, you can never control everything. ... It's hard for them to experience that from an educational point of view, they're used to being told like here's the equation to solve this, here are … the ten principles of sustainable design, apply each one of these principles, and the course is absolutely the opposite of that. That quagmire is real and the fact that they suffer is making me uncomfortable as a teacher but as I start to look back on it I see it as being generative.

In STE there was some agreement among the students that leading class discussion benefited whoever was leading a particular class, since they had to read more carefully and come up with questions to ask the others, but overall students appeared to prefer the discussions facilitated by the professor.

> **I:** The students leading is that a good part of the class?

> **SS7:** I kind of have mixed feelings ... I feel like it does encourage the people who are leading discussion to get a lot out of it ... but in the first few student-led discussions I kind of felt the absence of the instructor, where it was like okay we're coming to a standstill, we're saying the same things over and over again, why doesn't she jump in and get us back on track? ... [Now] we're more comfortable leading discussions and so we're getting better at it … I feel like at the beginning it was kind of a sink or swim approach where she just kind of was completely hands off and just saw what we did, and now that we've kind of gained our footing she's more comfortable coming in and helping us every once in awhile. ... I mean in some sense I feel like if she had held our hand more throughout the process we wouldn't have learned how to do it as quickly. ... So I mean I don't know if I would have any suggestions to make it better. ... [At first it] was really uncomfortable.

The instructor felt that while the student-led classes improved during the semester they often missed critical aspects of the reading and that she had to step in and highlight these. She suggested that the students' lack of previous experience of facilitating class discussions resulted in these class dynamics.

> **STE_I:** They don't get to choose [the readings] but by letting them choose which ones they present they can identify with some of the topics, they can take responsibility for them, they can pose the questions they want. I am kind of rethinking that this semester because it hasn't gone as well as I would have liked. ... I prepare too when I come in and I have my set of questions and if they don't get to those I jump in and interject mine ... it's sort of a scaffolded

> leading of discussion. If I were more organised they might turn in their questions to me ahead of time and I would meet with them and help them but that's a lot of extra work on my part. The class would probably go better if they did because they really don't know how to do it.

Developing skills for students to learn how to learn in these contexts becomes an important preparatory step.

Constructive course assignments

Student assignments were an important part of each course studied. These took one of two main forms: 1. Reflective essays or research updates where students often had to position themselves in relation to course readings. 2. Research case studies or group projects where students focused on a particular topic, situation or context. The latter type of assignment served as a significant part of each course both in terms of work and grading.

Relevant community based group project

An important aspect of E&SJ was the use of relevant (interdisciplinary) community based group projects focusing on issues such as uranium mining on land claimed by indigenous people. As an example, in this particular uranium project the students were introduced to a situation arising from discrepancies between federal and provincial law that resulted in the commencement of mining operations without consultation of the indigenous people claiming the land which usually is the norm. The students had to unravel a complex web of stakeholders and attempt to understand what was going on by conducting interviews and surveying literature and legal documents. They ended up proposing that the information they gathered could be used as a case study highlighting the complexities surrounding engineering practice. Like in most cases, this project team consisted of students from both engineering and social sciences. Thus, the projects gave students from different disciplines the opportunity to come together to learn from each other and break down stereotypes.

> **QS8:** A lot of people have preconceived notions of the typical engineer, the typical arts student and I think it was amazing to break that down and realise a lot of those preconceived notions are bullshit … It was really great to move out of that and I did have preconceived notions about your typical male engineering … I think that it was really important for me to … work with them and get to know them past my classmates and as friends and yeah I think they were amazing.

In addition, the projects gave the students something "concrete" to which they could relate the topics of readings and classroom discussion.

> **QS8:** I learned a lot from the project … You put in the dynamics or the things that you talk about in class and social justice and working together and community building and local initiatives and engaging with your world as a community … I talk about that kind of stuff all the time but to actually work within a group and look at an issue that's actually facing people today really shows me that if people do get together and work then little things can be done to help promote justice.

The projects also allowed the students to engage with a "real" social justice issue which made the learning experience more personal.

> **QS7:** I think it's important the projects happen because it gets your hands dirty and really makes you realise that we're talking about people being oppressed as a result of this or left out as a result of that. And you know we go and interview people I think it might give us the opportunity to realise who that is and give a face to these ideas … But, now if you're sitting in someone's house and they're telling you that they just can't afford the Internet and as a result you know they couldn't use these services with their telephone provider, they couldn't do this or they couldn't do that or they can't talk to their granddaughter because she doesn't like writing letters you know. I think that's when you really have to face those issues and come to terms with them somehow.

The projects offered different challenges for students of each discipline. The social science students were not used to working in group projects, but often had knowledge of required methods and some awareness of the issues at hand.

> **I:** Have found anything in the course challenging?
>
> **QS2:** The project is challenging I think, because … I'm not used to being in project groups and then making time. I'm just so used to this is your essay make your own time to write it, schedule it. I like scheduling when I'm gonna do what… with projects you never know, you have to change your schedule and make it work for everyone … working with people I guess.

The engineers on the other hand were used to work in projects but often lacked the required knowledge and awareness.

> **QSR1:** I found the project to be a tremendous learning experience. To be perfectly honest, when I first tried to do some work I was completely at a loss for how to proceed. I looked at material from other design projects I've done and tried to emulate the same process, but in a lot of ways I found it breaking down. Some of the concepts just didn't apply to projects of a social nature and even the ones that did seemed not to get me anywhere useful.

This student quote strongly echoes the discussion in Chapter 2 about the limitations of conventional engineering problem solving. Thus, in the context of the course, suitable project teams included people from both disciplines. The students were free to choose the projects they wanted to work on but were encouraged to mix across the disciplines and most project teams were mixed. Overall, the projects were positive experiences for many students.

> **QSR6:** When I first found out that I would have to be part of a group project involving engineering my first thought was, I hate group projects! My second thought, a little more disconcerting, was what can I ever contribute to this project? Three months later I can honestly say that this has been one of the most enjoyable assignments of my university career thus far, and definitively one of the most beneficial for my overall growth as a student. I cannot say enough about the three guys that I worked with on this assignment—they have changed my perspective on group projects drastically.

However, there was a trend in some of the project teams to split tasks up in accordance with disciplinary skills to better deal with a heavy work load and consequently for some students the project did not help their understanding of social justice in any major way.

> **I:** Have you found it useful to have the project in the course?

QS4: As a tool to making me aware of that?

I: Yeah, or how to deal with the issue.

QS4: For me I'd say personally not, but I'm again doing the more technical stuff. The seminars I prefer more, but I'm sure that these people might have more to say.

The use of case studies or term papers

In both STE and SDPC students carried out case studies on topics of their own choosing. How integrated the students' (individual) projects were into each course varied slightly with each class. In their interviews some of the students of STE commented that they saw few links between what they did in their case studies and what was discussed in class.

SS4: I think it's useful. I think it could be something other than a ten page research paper ... I'm having a difficult time applying the, whatever, skills we learn in class to doing the research because it feels just like another research paper.

I: So what would you have preferred?

SS4: [S]omething we could bring into class with us and discuss more … rather than having it be a ten page paper have it like smaller that we could present in class or something like that. And talk about it.

...

I: Okay so a little bit more interaction, a little bit like we did with the readings maybe?

SS4: Yeah, a little bit like that.

> **SS7:** I feel like [the assignments are] almost presented to us as something extra, where the bulk of the course is discussion, but the class right before something is due we'll have a ten minute discussion about what's due … I feel like it doesn't really encourage the working ahead even though we know we should be working ahead.
>
> **I:** Okay. So how would you do it? Would you have more integration? Bringing the papers into the class and sort of, or …?
>
> **SS7:** Maybe. I mean even maybe if we just for half of one class every couple of weeks we came in and broke up into small groups and discussed in pairs or in groups of three where we are with our research, what we're learning, how it ties in, just so that we're forced … if I knew that for Tuesday I have to have this much research done or whatever, and I have to be able to articulate it because I'm going to discuss it with someone, and then I know what they're talking about, I articulate what I'm thinking.

Work on the case studies was done outside of the classroom with support provided in the form of a session with the school's writing centre and feedback from the instructor on term paper (case study) proposal, outline and revised bibliography, and draft. The instructor commented that despite this support it was very clear that writing a term paper was something the students were un-practiced in and for the exercise to be potentially transformational for the students they need to get past the mechanics of writing. This is reflected in the following quote:

> **SS5:** I think it's important to note that the class is not just discussion in class … a huge chunk of the course is writing a paper … I can come to class and read and discuss, but the actual difficulty for me is sitting down and writing

> this term paper. … Writing is not my strong point so that's why I procrastinate. I'm putting it off as much as possible.

However, the same student appreciated the support that was given by the instructor:

> **SS5:** I'm slowly learning what an annotated bibliography is ... I really like how she's segmented the project, the paper. It's not like okay write this paper by December, it's okay I'm going to take you step by step through the writing process, because we don't really get that in the engineering classes, and like lab reports are not the same as writing a term paper. So I like how she's like okay first give me your topic, tell me what you want to write, then … get some sources, and then she gives us a second chance for a more detailed, and then having a draft, which I think is really beneficial if I take the time to utilise the opportunity as best as I can. So it's up to me to actually like write my rough draft as best I can so that I can get the most out of the [writing centre] I get the most out of her comments, like it's all up to me now.

The course instructor suggested that she might need to be firmer with deadlines so the students actually finish work on time and consequently can benefit from support initiatives such as the writing centre.

On the other hand, in SDPC significant time was dedicated in class for students to discuss work on their case studies with each other. Some students expressed scepticism toward this exercise beforehand:

> **RS5:** I think the idea of the project is a good idea because [it has] definitely given me time to look into something specific and I'm enjoying what I'm researching. ... I'm a little bit annoyed too that next week we're going to

> spend four hours ... talking about, with other students, how our project is coming, and it said on the syllabus that it was going to be case study working sessions, and I would really rather have those two hours to just … I would even just bring in my material and read it there in the class and get work done. ... I don't think anybody else has done significant research. I think everybody could use that time to work on it. ... I mean to exchange information maybe about what we're learning except that pointless because we're doing the presentations. I don't think we need to exchange information right now. I don't know because if we're all still in progress on our case study I don't really know how we're going to help each other.

However, many interviewees felt that this had been very beneficial especially in terms of helping them develop and expand their research on a process level.

> **RS10:** It helps to have someone else's perspective on the issues at hand, like sometimes you have a bunch of thoughts in your head and then when you try and explain them to somebody else you realise what you're really talking about. ... Oh yeah because when you try and explain them sometimes it makes more sense in your head and you realise that there's other elements that contribute to what you're trying to talk about that you maybe haven't specifically addressed and have to look more into. … I talked to probably two or three people that were able to offer really like critical points that I hadn't considered.

In contrast to the major assignments of the other two courses studied, in SDPC the case study was the exclusive focus during the midsection of the course. A few of the interviewees suggested that it might have been beneficial if work on the case study had commenced a bit earlier in the term as this would have given more purpose to their individually chosen readings.

> **RS7:** I really like the case study, because it's not like the individual readings where it was kind of oh you read an article, but then the next week we're onto a new topic so you can't really follow up that article very much. Whereas, the case study is everyone got to choose their own topic, but they get to go so in depth that it's worth it. So you learn so much about this and you can actually learn enough about it to actually take it to the bigger topic to discuss it so.

However, as the conceptual tools to sustainability introduced in the first section of the course were new to most of the students in one way or another, it was important to develop these tools a bit before using them in practice in the case study.

Summary of observations about course assignments

Overall, from the study of the three courses it can be concluded that course assignments can be a vehicle for students to focus their energy and knowledge in an area of their interest. However, it is desirable that course assignments link to or align with other moments of a course both to get reinforcement of central ideas and to provide a reflective dimension to something the students will spend much energy and time on. For example, as Zandvoort (2008) points out that community based service-learning projects are not enough by themselves; there needs to be something that adds an opportunity for students to reflect upon and contextualise their learning experience.

Some additional pedagogical observations

Other aspects noted in the E&SJ class in particular include the following:

Large range of media and intervention

The course readings covered a large range of topics and perspectives from texts praising technological development to texts dealing with anarchism or feminist perspectives on technology. The idea was to make the students understand the complexity of the topics and again that there might not be one right answer.

> **QS2:** Every week is something different, right? So the ideas were definitely broadened by that and the questions that people ask broaden it ... it's just you go into it further and you learn that through interacting.

In addition to different readings, variation and diversity in perspective and ideas were also expanded on by the use of video clips and presentations by guest speakers.

Topics seen from many perspectives with the potential of debate

An example of a video segment that sparked a lively debate in the class was the Seattle police's forceful handling of peaceful demonstrators during the World Trade Organisation's (WTO) meeting in the city in 1999. While this example did not explicitly relate directly to engineering it was an effective example of what Ursula Franklin (1999), who the students had read, refers to as a culture of compliance. Here is how two students reflected upon the film clip and the following discussion:

> **QS3:** Many engineers in the room were shocked by what was going on. If you buy into everything that's engineering then you have a hard time to agree with the protests.
>
> **I:** How did the engineers react?

QS3: For example they called the film biased. Yeah it was biased but was unapologetic about it and let it show.

QS8: So for instance when we were talking about the WTO protest riots in Seattle and about the police using physical force on the protesters. A few of the classmates said: Well they deserved it. And then, of course, you have this uproar between people who are like what do you mean they deserved it? … we get into discussions where people are going to disagree with one another, but that's the best part ... because I feel that change can only come from this kind of conflict and people thinking about it afterwards.

Real issues and guests

As an example of how a guest speaker engaged the class, Queen's University's Integrated Learning Librarian spoke of the potential of Facebook™ and similar web communities for social justice movements, but also of who owns what on the Internet and the potential dangers of monopolisation of virtual social spaces by private interests. This gave the students an issue that was relevant to many of them on a more direct level than, for example, Marx's writings about commodities.

I: Do you remember any part of the course … that sticks out?

QS6: The main thing that stands out for me is communication technologies because ... we read a of lot stuff by Ursula Franklin and … we were discussing about the impacts of communication technologies on societies. For example, [librarian] gave a talk about Facebook™ and our project is all about communication technology and its impact on social movements in Kingston.

> So what stuck out to me the most [was] discussing how these technologies are affecting our lives and our societies and everything.

A topic that was focused on through the use of film and by a guest speaker was the recovered factories of Argentina. This was a concrete example that challenged the students' notions of both people's goals and how industry works and showed them that there can be alternative business models than those they were used to from a North American context.

> **QS7:** I found it really inspiring that people had proven that if you want to make a living, you know these people aren't making profits per se, I mean obviously they are but they're not answering to shareholders every quarter and coming up with bigger and better numbers. They're just making enough to feed their family … I really want to imagine that these people really don't want more than just to live lives that are free from hunger … it's hard to imagine at least in my mindset that that's actually true ... but at the same time it's very inspiring to see that humbleness and the idea that you could work for something because you need to eat, but not have this bigger and better goal. Yeah it's hard not to say those kinds of things, but have this greater goal of having more than you know the Smiths next door.

Variation Theory: Incorporating the Results of Research

In a previous publication (Kabo & Baillie, 2009a) we suggested drawing on the outcome of that study as an exercise. A version of that exercise was implemented in the 2009 iteration of the *Engineering and Social Justice* (E&SJ) course. The main idea was at an early stage of the course the instructors would expand the students' understanding of social justice by having them see it through the eyes of other students. This was done by having them work in their project groups and read through a selection of quotes about social justice from the interviews with the previous year's students. Each quote, of 50 in total, corresponded to one of the nine conceptions discussed in Chapter 4, except for a few that had not been assigned to a category. The rationale, drawing on variation theory (Marton & Tsui, 2004) as discussed in Chapter 2, was to expose the students to variation in how social justice is understood by someone in a similar context as the students themselves and because this would help students know what the critical aspects are which in turn would help them develop a more complex understanding of social justice and move further along the liminal spectrum.

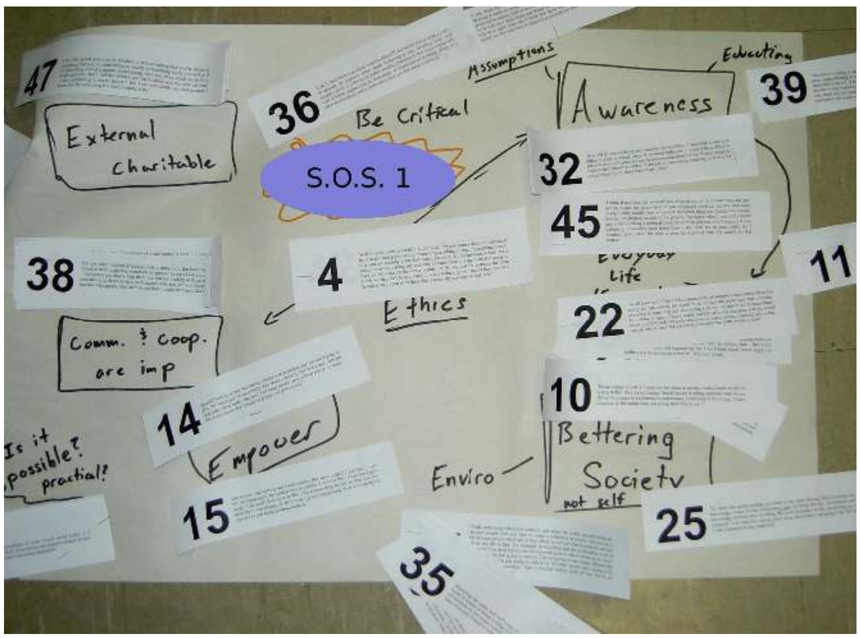

Figure 11: An example of a student outcome space (S.O.S.)

In addition to reading the quotes, the students were asked in very general terms to construct an outcome space by grouping quotes as they saw fit and pointing out any relations between the groupings. Examples of this can be seen in Figure 11 and Figure 12. In retrospect more instructions of what we (Kabo et al., 2009) expected the students to do could have been given, since there was a degree of confusion present in the class during the exercise, which is reflected in this student feedback:

Student A: I found it really interesting to read what other students had written. I really wondered about the surrounding context of the short paragraphs we read, and how the paragraphs were selected.

However, the following student feedback suggests that the exercise achieved its aim:

Student B: I really enjoyed the quote exercise. I could see a lot of myself in some of the quotes, and at the same time a lot of views that I definitely do not share. One thing I found is that they helped to clarify some of my views on social justice as I had the opportunity to evaluate whether or not I agreed with the statements being made.

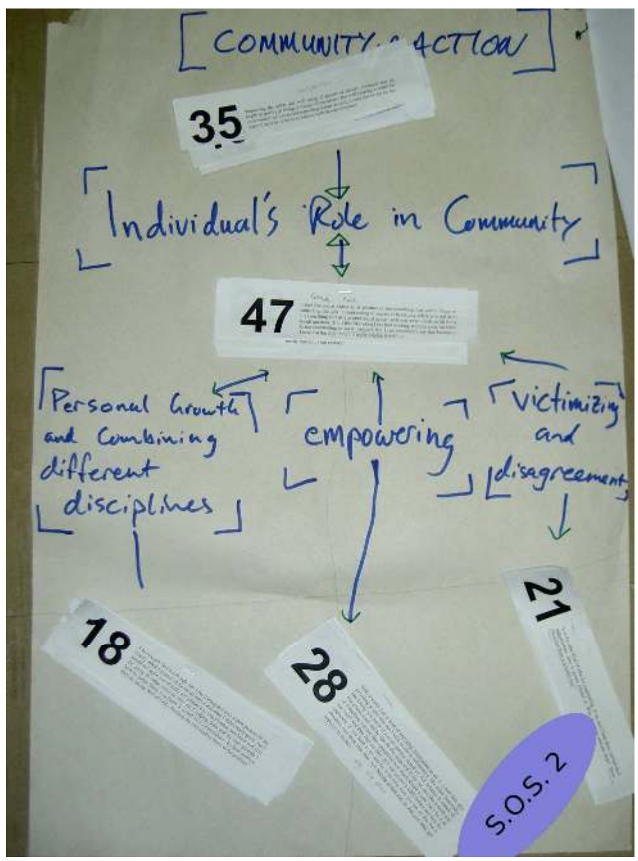

Figure 12: Another example of a student outcome space

Concluding Summary and Reflections

The three courses studied in this doctoral project share a number of key pedagogical characteristics. They are all relatively small (8, 15, respective 30 students) seminar-based classes in which the instructors mainly take the role of facilitator of class discussion (when this role is not ceded to the students) and the aim is to create a constructive and respectful learning environment that facilitates student empowerment. As can be seen in preceding chapters, the pedagogical practice used in each course appear to help students move toward desired learning outcomes and was generally seen in a positive light by students (Kabo et al., 2009; Nieusma, 2009; Riley, 2008b). The format of seminar based discussion appear to be an almost necessary prerequisite for this kind of class as it allows the students to engage with the topics at hand. An observed challenge is for instructors to provide enough structure and support for students while still giving the students a chance to take ownership of the topics covered in class and of their own learning. Additionally, interdisciplinarity offers both opportunities and challenges. While mixing disciplines can broaden discussion and bring additional perspectives, it can also cause difficulties in communication across disciplines if care is not taken initially to create some sort of common ground for the students in a course. Ideally, two professors from different disciplines will work together, but if that is not an option, then it is important that the course instructor can play both sides to act as an interpreter. Another challenge arises if one wants to make these kinds of classes available to a greater number of students as small class size and term long engagement with the course topics are essential for constructive student learning and growth.

Chapter 8

Discussion

Up to this point, the exploration of engineering and social justice focused on in this dissertation has mainly been discussed in terms of the isolated contexts of each of the three courses studied. In this chapter, a more holistic perspective is adopted and the discussion is broadened by comparing and contrasting the different studies. In addition, the nature of the data and outcome spaces, the research process, the conceptual model developed and utilised, and the implications of the findings are explored and reflected upon. This chapter is broken down in two parts: in Part I the three studies reported on in this dissertation and the corresponding findings are compared, contrasted, and reflected upon; in Part II the proposed conceptual model is reflected upon in relation to threshold concept theory and a potential avenue for further development of the model in more non-linear terms is explored.

Part I – Reflections and Lessons from the Three Studies

Comparison of the three social justice outcome spaces

In the preceding four chapters the "what" and "how" of learning as well as key pedagogical characteristics of the three different courses studied in this dissertation were discussed. Now these different threads will be drawn together in light of the emerging implications for (engineering) education aimed at the themes of social justice and critical thinking.

First, the social justice outcome spaces that emerged for each course are compared. Here it is important to remember that in phenomenography (and in other qualitative research approaches) findings are tied to the context studied and cannot, in most cases, be generalised to a wider context, i.e., by studying engineering and social justice at Queen's University it is not possible say that observations made in that context are true for all (North American) engineers. Nevertheless, due to the thought collectives that shape and connect (North American) engineers and engineering students, it should be possible to say something about the implications the findings of this study might have for a wider context. Also, through the study of three different courses critical variation was added to the overall study and by comparing and contrasting the courses and their respective social justice outcome spaces triangulation of sorts can be achieved.

Dimensions of variation between the three course

As should be evident from reading the four preceding chapters, quite a few qualities and characteristics were shared between the three courses studied, while at the same time each course had its own distinct nature. In this section, some of these dimensions of variation are discussed.

The main aspect shared between the three courses was the course instructors' ambition to encourage students to develop their critical thinking (as in seeing beyond "common sense") abilities and broaden their conceptions of engineering and problem solving. In each course this aim manifested in a different way: in *Engineering and Social Justice* (E&SJ) social justice was used as a critical lens, in *Sustainable Design Politics and Culture* (SDPC) sustainability was used as a lens in a similar manner, and in *Science, Technology, and Ethics* (STE) questioning objectivity served as a starting point for a discussion of the wider ethical implications of engineering and science practice in a range of areas. Thus, a major dimension of variation between the courses was the type of lens through which the process of developing critical thinking and broadening horizons was focused.

Another dimension of variation was to what degree and how social justice was emphasised in each course. In E&SJ an explicit stress was put on social justice, for example, through the choices of readings and topics discussed in the classroom; in SDPC and STE social justice was, for most of the time, not explicitly focused on, but was at the same time implicit to varying degrees in each course context.

Yet another dimension of variation was the different pedagogical approaches instructors used in their classrooms, as exemplified in the preceding chapters. For example, while respectful probing dialogue was the norm in each course, different instructors approached this in their own way. One of the E&SJ course instructors, Richard Day, for example, alongside his “jazz” style of teaching, utilised what he calls “pedagogy of the insane” to in a quite direct way confront the students with the key points of the topic at hand while at the same time debating with his co-instructor. Of course, this particular instructor was on sabbatical when the social justice outcome space for this course was constructed, but the debate dynamic was still present due to the team teaching aspect of the course. The SDPC instructor, on the other hand, preferred a more indirect approach and tried to back students into new understandings. He referred to his teaching method as Socratic in that he always asked the next question, e.g., “yes but what about this and what about this and what about this?”, so that students would find their own way to answers that worked for them. The STE instructor, yet again, framed her teaching through what she referred to as pedagogies of liberation, which encourage students to take ownership of their learning. As an example, the instructor chose to cede facilitation of class discussion to her students for most of the term, while still being there to step in if they missed critical points.

Other dimensions of variation between the three courses included class size, mix of disciplines, and my own level of participation in the class. E&SJ was the largest class with up to 30 students from engineering and social science. As participant observer I was quite active in class discussion. SDPC was the midsized class with 15 active students from mainly technical disciplines such as architecture, design, and engineering. In this class I took a more passive role both due to a lower number of common readings and the fact that I only attended one out of two weekly class sessions. STE was the smallest class with 8 students with ties to engineering. Due to small class size, use of common readings as base for most discussion, and the fact that I was present in most classes, I was an active participant and sometimes debated with the instructor in a manner similar to the dynamic that existed between the two instructors of E&SJ.

Thus, based on the differences in these various dimensions of variation, which have been summarised above, it is not surprising that the three social justice outcome spaces that emerged differ somewhat in appearance, content, and focus. However, there are also significant similarities between them. The three outcome spaces can be seen side by side in Figure 13.

Trends in and variation between the three outcome spaces

To facilitate a rough comparison of the different liminal positions between the three outcome spaces an attempt has been made to correlate the liminal positions of SDPC and STE with those of E&SJ. The rationale for using the outcome space of E&SJ as the norm is that this outcome space was created from the largest and richest set of data (25 transcripts from interviews and focus groups with quotes selected from 14 different students). Also, the explicit focus on social justice in this course likely contributed to data of a less vague nature than some of the data collected from the other two courses. Table 3 shows an approximate comparison of liminal positions in the three outcome spaces.

	Social justice as no understanding, misconceptions, or contradictions	Social justice as fragmented understanding or isolated characteristics	Social justice as helping or responsibility (passive and one-directional)	Social justice as changing or improving society (active and participatory)	Social justice as a lens for critical analysis and deconstruction
E&SJ	A	B	C	D	E
SPDC	ω1	ω2	ω3, ω4	ω3, ω4, ω5	(ω5)
STE	α0	α1, β0, β1	α1, α2, α3, β1	α2, (β2), γ1, (γ2)	(β2), (γ2)

Table 3: Approximate comparison between liminal positions in the three outcome spaces

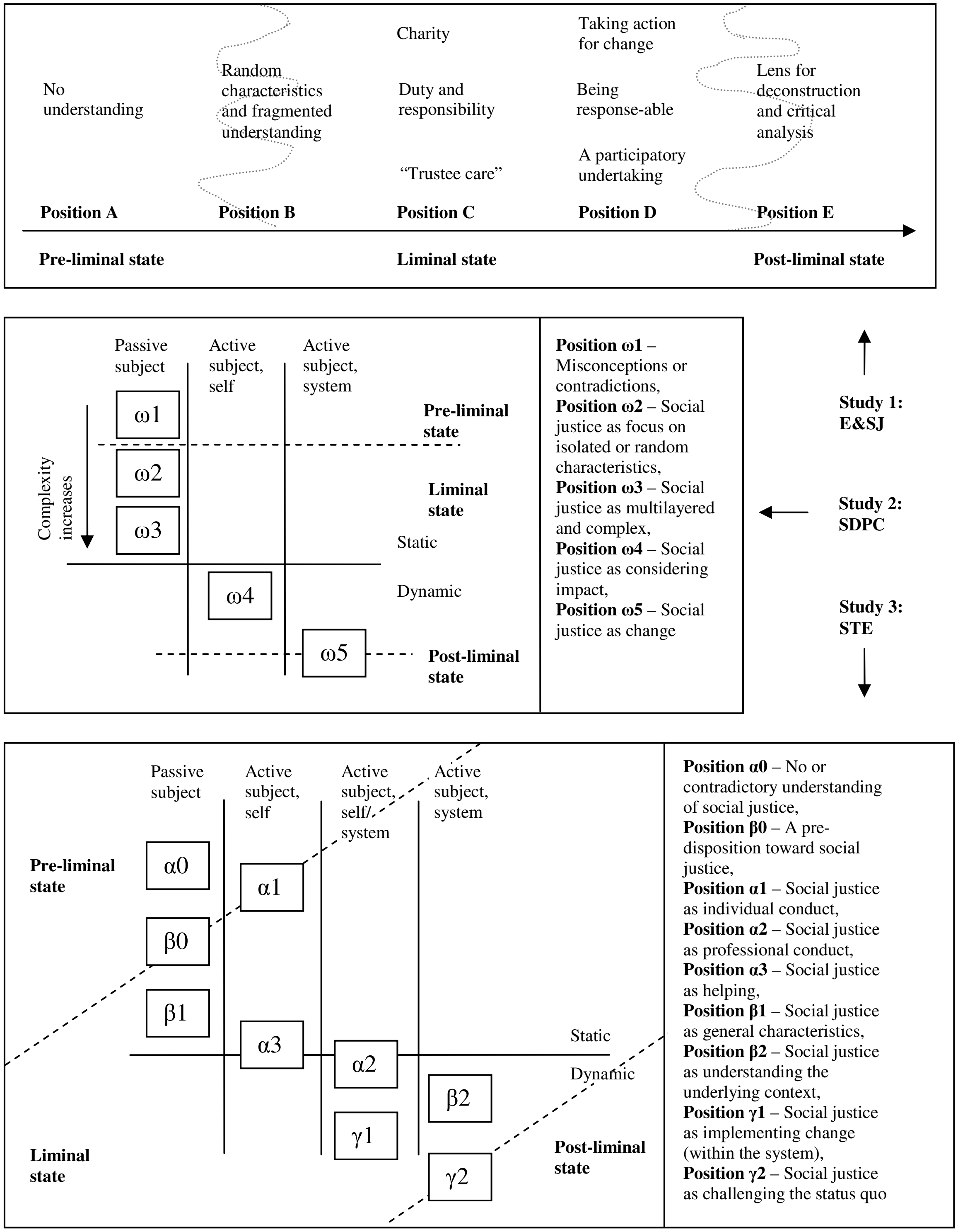

Figure 13: Three social justice outcome spaces

As can be seen, in most cases there is no direct correlation between positions in different outcome spaces, but rather there is overlap between multiple positions. All three outcome spaces display a similar trend with positions (conceptions) going from a pre-liminal state of misunderstandings and contradictions through a liminal state toward a post-liminal state of critical analysis and deconstruction. However, of the three, the E&SJ outcome space displays a position (*Position E* – Social justice as a lens for critical analysis and deconstruction) closest to the post-liminal state or the position might even be counted as post-liminal. The most advanced positions of STE and SDPC (*Position γ2* – SJ as challenging the status quo and *Position β2* – Social justice as understanding the underlying context respective *Position ω5* – SJ as change) might belong to the post-liminal state or lie in the borderland between the liminal and post-liminal states and have more in common with *Position D* (SJ as something active and participatory) of E&SJ. Overall, the general trend can be described as moving from "Social justice as no understanding, misconceptions, or contradictions" to "Social justice as fragmented understanding and/or isolated characteristics" to "Social justice as helping and/or responsibility" to "Social justice as changing society" to finally "Social justice as a critical lens." Most of the positions appear to exist in the liminal state of the liminal space which indicates that most students have entered the threshold of social justice. Figure 14 provides a visualisation of the liminal outcome space model used to organise and compare the findings.

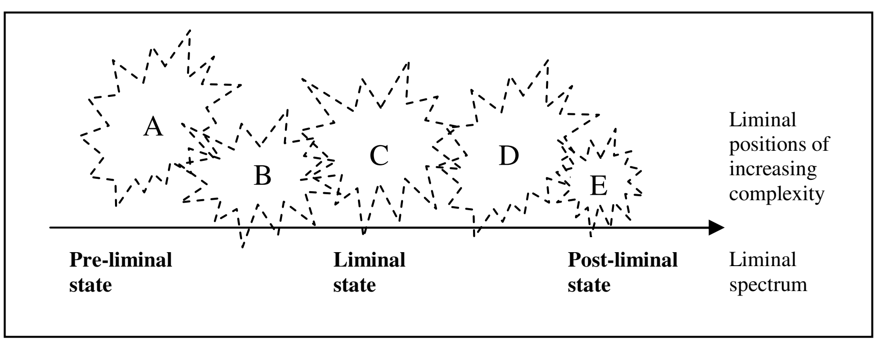

Figure 14: A recap of the liminal outcome space conceptual model

Framing of data and outcome space structures

At this point it is important to discuss how the data was framed in each of the three outcome spaces. In *Engineering and Social Justice* (E&SJ), five different liminal positions and nine different conceptions of social justice were identified. The two liminal positions corresponding to the liminal state of liminal space contain three conceptions each, while the other three liminal positions correspond to one conception each. In *Sustainable Design Politics and Culture* (SDPC), due to the data relating to social justice not being as rich and more diffuse in nature, five liminal positions of a more general nature were identified. The liminal positions were not broken down further into more well defined conceptions. However, the five liminal positions do represent critical variation. The outcome space of *Science, Technology, and Ethics* (STE) fell somewhere in the middle as the data referring to social justice mainly was indirect and implicit in nature, but at the same time, there was not a dominant course discourse present, as was the case with sustainability in SDPC. Nine liminal positions were identified. Some of these emerged more strongly than others and some take on the nature of well defined conceptions.

Implications of the comparison of the three outcome spaces

One aspect worth noting when comparing the three social justice outcome spaces is that neither *Sustainable Design Politics and Culture* (SDPC) nor *Science, Technology, and Ethics* (STE) gave rise to any liminal positions that are radically different from the positions and conceptions of social justice emerging from *Engineering and Social Justice* (E&SJ). Yes, they do offer slightly different framings and perspectives, but they offer no new significant themes. This indicates that a focus on sustainability or ethics (even in a wide macro ethics way) does not to any greater extent add anything major to help engineering students understand social justice. However, this is not to suggest that SDPC and STE were not successful in achieving what they were intended to do. On the contrary, as could be seen in Chapter 5 and 6 both courses appear to encourage their students to engage with critical thinking and in the case of SDPC a well developed sustainability outcome space emerged from the data, which correspond well with the course instructor's intentions for the course. However, it does appear that if one is interested in developing an articulated understanding of social justice in students then an explicit focus on social justice is preferable.

The applicability of the findings for engineering

The question of how representative these findings are for engineers' conceptions of social justice can be raised. This question has relevance as two of the classes—*Sustainable Design Politics and Culture* (SDPC) and *Engineering and Social Justice* (E&SJ)—were interdisciplinary in nature and therefore the students interviewed were mixed. In the case of E&SJ it can be argued that the outcome space is fully representative of the engineers who participated in the study (and more broadly to the engineers in the class) as out of the 14 students who provided quotes to the construction of the outcome space 11 were engineers. Also, during the data analysis process, for each quote the discipline of the interviewee was noted and when the outcome space was finalised care was taken to ensure that a quote from an engineer was included in each category. This should not be seen as an artificial restriction was imposed on the data analysis or the outcome space as this measure was taken at the end of the process and the engineering students were naturally present in all conceptions and liminal positions. The social science students helped to flesh out the outcome space, but they did not add any conceptions unique to them as a group.

The findings are deemed representative for SDPC also even though there was a smaller number of students and hence overall a smaller number of engineering student interviews. Despite this all interviews were with technical students from a range of disciplines—not as different from one another as in E&SJ. Thus, the discussion above should be indicative of engineering and social justice in the contexts studied as well as in a broader North American context.

Thoughts on participant observation

During the research project reported on in this dissertation, when I attended a course to observe its classroom dynamics, I was not just a passive observer, but rather an active participant in class discussion (as stated above). In this section potential implications and consequences of this approach are reflected upon. To situate this reflection here follow a few perspectives on participant observation from different scholars. First, Atkinson and Coffey (2003) observe that:

> In the case of observational work, claims have been made that participant observation enables the researcher to participate firsthand in the happenings of the setting; these claims have been countered, of course, by warnings that the researcher may affect (contaminate) the setting or becoming too much of a participant, and thereby lose the capacity to observe critically. (p. 119)

The first sentiment is echoed by Jorgensen (1989) who highlights what he considers the unique strength of the approach:

> The participant role provides access to the world of everyday life from the standpoint of a member or insider. ... Participant observation, in other words, is a very special strategy and method for gaining access to the interior, seemingly subjective aspects of human existence ... Through participation, the researcher is able to observe and experience the meanings and interactions from the role of an insider. (pp. 20-21)

A key question for Jorgensen is how the researcher can gain and maintain access to the group or population under study. Friedrichs and Lüdtke (1975) also see the strength of the approach, but echo the second perspective mentioned above by Atkinson and Coffey, when they reflect upon how active a participant observer should be in the context studied:

> As a general rule it can be said: the observer should attempt to proceed from peripheral to integral roles, however, only to the extent his [*sic*] behaviour does not give rise to uncontrollable impacts and power effects, which change the social structure, or to affirmations of a given party in the field. (p. 161)

While Friedrichs and Lüdtke's offer this "rule" as a caution Atkinson and Coffey (2003), who write from a postmodern perspective, question the wisdom of spending too much energy on such concerns.

> Through both participant observation and interviewing there is the potential for "contamination," although this is a paralyzing and unhelpful way of characterizing the research process (and can actually render all research inadequate). Rather, through active reflexivity we should recognize that we are part of the social events and process we observe and help to narrate. To overemphasize our potential to change things artificially swells our own importance. To deny our being "there" misunderstands the inherent qualities of both methods—in terms of documenting and making sense of social worlds of which we are a part (either through participant observation or as facilitators of shared accounts and narrative strategies). (p. 120)

The key point here is that when researchers choose to engage with a context they will affect it in some way and the important thing is to be reflexively aware of how one chooses to engage. In the studies discussed in this dissertation it was a conscious choice to actively participate in class discussions. This was done in order to for me, the researcher, to get a better understanding of the context in question through my own subjective experience and to, in a sense, become a member of the class so the students could establish a relation to me as a person in order to contribute to maintaining a relaxed learning environment and to facilitate interviewee requirement. Here it should to be noted that these aims differ somewhat from how participant observation is discussed by Jorgensen (1989) and Friedrichs and Lüdtke (1975), who focus on it as a primary data gathering approach that relies heavily on extensive field notes. In the studies of this PhD project, notes were kept, but observations were intended to compliment and give context to the interviews, which were the main data source.

It is quite likely that my active participation in class discussions only had minor or negligible impact on the outcome spaces of the studies since on most occasions the course readings were the main driving force of the discussions and often I was learning together with the students. In addition, the outcome spaces (for social justice) were drawn from the student interviews and these were mainly driven by the interviewees' experiences of the course in question and all data was analysed using the phenomenographic iterative approach described in Chapter 3.

Implications for teaching for engineering and social justice

While it is clear that the three courses studied in their own respective ways (as discussed in Chapters 4-6) are successful in helping some students develop their ability to think critically and start moving toward the desired learning outcomes of each course, it is also clear that not all students are achieving these goals. As suggested at the beginning of Chapter 7, it is likely the students need to adopt a deep approach to their learning to successfully navigate the liminal spaces connected to approaching critical thinking in general and social justice in particular. Actually, since the emphasis in the courses studied was less about *knowing more* about something (e.g., engineering) and more about *knowing* something *differently*, it makes sense that students' approaches to learning are closely intertwined with their ability to navigate liminal space. Booth (2004) reports that phenomenographic studies of learning "have shown decisively that a deep approach [to learning] is connected with grasping of critical features of subject matter, while a surface approach, being a temporary response to the immediate situation, gives knowledge that is easily misunderstood and quickly forgotten" (p. 17). In light of this, the question becomes to what extent the different courses studied are successful in encouraging students to adopt a deep approach to their learning.

Overall, as discussed in Chapter 7, it appears that the basic pedagogical model (seminar style classroom, small class size, continuous emphasis on critical thinking, high level of student responsibility and autonomy, constructive and engaging assignments, and self-reflexive instructors who act more as facilitators than lecturers) used in each of the three courses, and which is in line with Freire's (1970) idea of problem-posing education, offers a quite robust foundation to build a learning environment which promotes a deep approach to learning. However, some students would with varying frequency adopt a surface approach to their learning. For example, discussion of (common) readings was a core part of each course, but there were occasions where class discussion was hampered by the fact that a significant number of students had not done the reading in question. While some students suggested that they still got something out of being in the classroom and listening to their peers discuss; to actively participate in the discussion in a meaningful way they needed to have done the reading. Also, if too many people had skipped on a reading class discussion became very limited. On these occasions, these students can be said to have taken a surface approach to their learning in regards to this aspect of the course. The following student offers a partial explanation for this behaviour:

> **RS9:** I mean for a lot of people reading 100 pages a week isn't feasible because this is [University] and unfortunately the stigma of the type of student and what's required of them at this institution is very low. At most people read less than 20 pages a week just for any class. This class requiring that level of reading is daunting to people that aren't capable of reading for that quantity and pulling ideas out or being able to dedicate the time to read that much. I mean it's been a challenge for me personally and … I had a lot of exposure to it before.

This quote highlights the fact that many engineering students might not be used the amount of reading (approximately 50-100 pages per week) or the kind of reading the courses required. Thus, it is important for instructors to consider the previous knowledge, skills, and experiences of their students and how these can be bridged with the instructors' ambitions for the students, this is no small challenge, especially in an interdisciplinary classroom where the range in students' abilities and interests can be quite diverse.

Course effectiveness

In response to the observation above that not all students reached the desired outcomes of the course they attended, the question of what can be achieved in one course during one term can be asked. As discussed in Chapter 2 it is not trivial to first become aware of and then potentially challenge the "common sense" ways of thinking of the thought collectives one belongs to. In addition, as the course instructor of SDPC commented during his interview, topics such as social justice and sustainability are by their nature complex and not easy to understand. It is quite likely an unrealistic goal to expect all students in a class to successfully navigate their way through the liminal space in question to reach the post-liminal state, as they most certainty will start their journeys from different positions at the liminal spectrum and with different pre-dispositions toward adopting social justice as a critical lens and/or develop their critical thinking ability. However, what the type of courses studied are likely to be able to achieve is to start students on their journeys toward becoming more critical thinkers or help them get unstuck if they are stuck somewhere in liminal space, as suggested by this student quote:

> **QS13:** This course has had a huge effect on my way of thinking. Big time! … It really messed with my head. Sometimes I was scared to go to class because I didn't want to think about stuff … I feel now that I look at things from a different perspective or CAN … I feel I'm going to think more socially about making certain decisions.

Of course, each of the classes studied were electives and this likely resulted in a degree of self-selection among the students. Indeed the majority of the interviewees expressed that they had a previous interest in respective area of study of the course they attended or that the course description had appeared intriguing to them. There were very few students among the interviewees who only had picked their class because there was nothing better to choose in its place. The challenge remains as to whether it is possible or desired to scale up these courses so that every student may benefit from them.

The contribution of this study to existing and future educational practice

Regardless of the challenges of expanding the type of educational efforts studied in this dissertation to a wider group of students, the findings of this research can be used as input to pedagogical practices in already existing courses as well as those yet to be designed. Drawing on variation theory, as suggested in Chapter 3 and tried in practice in the study reported on in Chapter 7, the liminal positions and conceptions that were identified in the various outcome spaces can be used to illustrate dimensions of critical variation of, for example, social justice. As Marton et al. (2004) suggest:

> We are not arguing for variation in general, and we are not saying the more variation there is, the better the possibilities to learn. What we believe is that variation enables learners to experience the features that are critical for a particular learning as well as the development of certain capabilities. In other words, these features must be experienced as dimensions of variation. (p. 15)

These dimensions of critical variation can be framed by the conceptual model proposed in Chapter 3 and discussed above (Figure 14), i.e., the variation around conceptions at different places on the liminal space will allow students to move through the threshold. For example, by drawing on the outcome space from E&SJ, students could discuss and understand what the difference might be between being charitable and being socially just, being aware and taking action or what it means to involve clients in a participatory way, as part of the process of adopting social justice as a lens for engineering practice. The emerging perception shifts of engineering that also were identified in the study of E&SJ or the perspectives on sustainability emerging from the study of SDPC can be discussed in a similar manner.

Part II – Reflections on the Proposed Conceptual Model

In this dissertation the notion of adopting a critical lens has been explored, with a main focus on social justice as a lens for engineering. At the same time, a conceptual model for framing this process was developed. In this section, some aspects of this model, its relation to threshold concept theory (TCT), and overall usefulness are reflected upon.

At the core of TCT is the elegant, yet simple metaphor of the threshold, which is applied to certain transformative and troublesome learning experiences, which in turn (often) are tied to the characteristic concepts that have given name to the emerging framework. Additionally, from TCT the useful ideas of liminal space and variation in different liminal states have emerged. While neither of these ideas are new, e.g., Carl Jung used the term liminality to describe the emotional and behavioural oscillation of men (in particular) going through a midlife crisis (Meyer & Land, 2006b), the way they have been used in TCT has stirred up quite a bit of interest among educational researchers and practitioners (e.g., see Flanagan, n.d., for examples). Aspects of TCT have been useful for framing the research discussed in this dissertation. However, to some extent the work reported herein runs contrary to the part of TCT that discuss the process of acquiring the conventional ways of thinking and practicing of a particular community of practice, as efforts to include new ways of thinking and seeing into a disciplinary community have been explored. Rather, it was hypothesised that seeing through a critical social justice lens might be seen as a threshold for the whole discipline of engineering, and through the research conducted in this study empirical support for this idea have been found.

To frame this idea of a threshold for a whole discipline, or similarly the process of acquiring new lenses that are likely to challenge how one views oneself and the world, insights were drawn from Fleck's (1979) ideas about thought collectives and Gramsci's (1971) ideas about hegemony. Similar to the conventional TCT idea that adopting the ways of thinking and practicing of a discipline might involve navigation of liminal spaces, challenging one's own "common sense" understanding of the world with new ways of thinking and seeing also involves entering into a liminal space. While Meyer et al.'s (2008) idea of different liminal states was never meant to be interpreted as referring to separate phases of learning, in this dissertation this idea was reframed by introducing the idea of a continuous liminal spectrum in order to better capture the fluid nature of liminal space. To explore students' navigation of the proposed social justice liminal space, phenomenographic variation theory was combined with TCT to create a conceptual framework that provided a research approach suited for this endeavour. Characteristic for this approach is that the outcome space represents a mapping of liminal positions of increasing complexity along a liminal spectrum or space. This conceptual model and corresponding research approach has served well to frame and explore a group of engineering students' attempts to approach adopting social justice as a critical lens to view their future practice and profession. However, as is the case in phenomenography, this is an approach for studying learning on a collective level with the advantages and disadvantages that come with that. If one would wish to follow the learning journey of a particular learner, then another approach would be needed.

In addition to being useful for framing (and exploring) social justice as a critical lens toward engineering, the conceptual model has also proven transferable to other (similar) contexts, for example service learning in a cross-cultural context (Baillie et al., in press).

Implications for threshold concept theory

There have been some concerns (e.g., Savin-Baden, 2008) raised that threshold concepts through their links to the conventional ways of thinking and practicing (WTPs) of a discipline might take on a hegemonic role within the discipline in question. However, proponents of threshold concepts (e.g., Cousin, 2008) argue that they are not supposed to work in that way and that they always are theorised as "provisional, contestable and culturally situated" (p. 263). However, through the research presented in this dissertation indications have been found that dominant disciplinary ways of thinking can, indeed, be hegemonic and that this in turn can create thresholds for a whole discipline in terms of adopting alternative ways of thinking. Since threshold concepts are envisioned to be linked to the WTPs of a disciplinary community, this is an important point, and thus, threshold concept researchers need to pay attention to the impact on a discipline of "common sense" WTPs. Furthermore, this discussion brings to the forefront the question of expertise and who it is that may judge what the accepted ways of thinking are within a community of practice. Taken together, these concerns suggest that further investigation of the underpinnings of TCT might be a good idea, for example, by applying a *Foucaultian* lens to the framework as part of Foucault's (1980) scholarly project was aimed at understanding relations of power and discursive formations.

Continued evolution of the conceptual model

While the conceptual model discussed above served the purposes of this dissertation well, it has also received (informal) critique from colleagues in the social sciences, who have commented that the model can be perceived to suggest that the nature of learning is linear. However, this has never been the intention. Indeed, the mapping of the liminal space of social justice is in line both with the phenomenographic idea that students can hold several conceptions of the same phenomenon simultaneously and with the idea of oscillation between different liminal states suggested by threshold concept theory; both of these ideas strongly suggest a non-linear nature of learning. However, it is understandable that the idea of learners moving along a liminal spectrum toward increasingly complex conceptions or ways of seeing can be interpreted as suggesting that learning is linear in nature. In response to these concerns the question was asked of how the conceptual model could be further improved and developed in more non-linear terms.

Land et al. (2006), when discussing the potentially recursive nature of a learning process, by drawing on the work of Deleuze and Guattari's (1987), suggest that:

> Perhaps the connected design challenge for teachers is to opt for a more rhizomorphic than tree-like structure for their module or course (Deleuze and Guattari, [1987]). Whereas the latter implies a hierarchical, incremental building-up of understanding, the former would construct points of entry into learning from a number of places. (p. 202)

Drawing on botany, Deleuze and Guattari's (2004) develop the metaphor of the rhizome:

> Let us summarize the principal characteristics of a rhizome: unlike trees or their roots, the rhizome connects any point to any other point, and its traits are not necessarily linked to traits of the same nature; it brings into play very different regimes of signs, even nonsign states. ... It is composed not of units but of dimensions, or rather directions of motion. It has neither beginning nor end, but always a middle (milieu) from which it grows and which it overspills. ... Unlike a structure, which is defined by a set of points and positions, with binary relations between the points and blunivocal relationships between the positions, the rhizome is made only of lines: lines of segmentarity and stratification as its dimensions, and the line of flight or deterritorialization as the maximum dimension after which the multiplicity undergoes metamorphosis, changes in nature. ... Unlike the graphic arts, drawing, or photography, unlike tracings, the rhizome pertains to a map that must be produced, constructed, a map that is always detachable, connectable, reversible, modifiable, and has multiple entryways and exits and its own lines of flight. It is tracings that must be put on the map, not the opposite. In contrast to centered (even polycentric) systems with hierarchical modes of

> communication and preestablished paths, the rhizome is an acentered, nonhierarchical, nonsignifying system without a General and without an organizing memory or central automaton, defined solely by a circulation of states. (p. 23)

The idea of rhizomatic education has gotten some traction in the context of online learning (Cormier, 2008). To further develop the conceptual model of an adapted phenomenographic liminal space proposed in this dissertation and to (re)imagine it in more non-linear terms inspiration was drawn from Deleuze and Guattari's (1987) book *A Thousand Plateaus*, which in turn draws from a psychology and philosophy postmodernism as well as radical social thought. Massumi (2004), in his "Translator's Foreword" describes *A Thousand Plateaus* in the following manner:

> This is a book that speaks of many things, of ticks and quilts and fuzzy subsets and noology and political economy. It is difficult to know how to approach it. ... [The] authors recommend that you read it as you would listen to a record? ... How should *A Thousand Plateaus* be played? ... *A Thousand Plateaus* is conceived as an open system. It does not pretend to have the final word. The authors' hope, however, is that elements of it will stay with a certain number of its readers and will weave into the melody of their everyday lives. ... The reader is invited to follow each section to the plateau that rises from the smooth space of its composition, and to move from one plateau to the next plateau. But it is just as good to ignore the heights. You can take a concept that is particularly to your liking and jump with it to its next appearance. They tend to cycle back. Some might call it repetition Deleuze and Guattari call it a

> refrain. Most of all, the reader is invited to lift a dynamism out of the book entirely, and incarnate it in a foreign medium, whether it be painting or politics. (pp. ix-xv)

In particular, the re-imagining of the conceptual model put forward in chapter 3 draws parallels to the chapter "Of the refrain" in *A Thousand Plateaus*. While much of their discussion ties into musical themes, Deleuze and Guattari (1987) offer the following definition:

> In a general sense, we call a refrain any aggregate of matters of expression that draws a territory and develops into territorial motifs and landscapes (there are optical, gestural, motor, etc., refrains). (p. 323)

The act of navigating a liminal space can be thought of in a similar light. Deleuze and Guattari discuss three aspects of the refrain: chaos, territory, and cosmos. These can be mapped onto the pre-liminal, liminal, and post-liminal states of liminal space as per Meyer et al. (2008).

> The refrain has all three aspects, it makes them simultaneous or mixes them: sometimes, sometimes, sometimes. Sometimes chaos is an immense black hole in which one endeavors to fix a fragile point as a center. Sometimes one organizes around that point a calm and stable "pace" (rather than a form): the black hole has become a home. Sometimes one grafts onto that pace a breakaway from the black hole. (Deleuze and Guattari, 1987, p. 312)

The pre-liminal state can easily be seen as chaotic with a fragile point at the centre—the initial outline of a new conception of a phenomenon or way of seeing. While liminal space is a "place" of flux and uncertainty, the liminal state is a process or attempt to grasp the "concept" and create a semi-stable order in the chaos. This is the creation of a (temporary) territory. The breakaway from the black hole is similar to exiting the liminal space (the post-liminal state). Deleuze and Guattari (1987) expand on this breakaway further:

> Finally, the point launches out of itself, impelled by wandering centrifugal forces that fan out to the sphere of the cosmos: one "tries convulsively to fly from the earth, but at the following level one actually rises above it … powered by centrifugal forces that triumph over gravity" (Klee cited by Deleuze and Guattari). (p. 312)

This opening up to the cosmos can be paralleled to seeing the world through a new lens and/or a new more holistic understanding of the phenomenon in question. Thus, Meyer et al.'s (2008) discussion of liminal space can be mapped onto Deleuze and Guattari's discussion of the refrain, but what have been gained from drawing this parallel? A more comprehensive metaphor or visualisation of learners' potential journeys through a liminal space—journeys from chaos through territories to cosmos! Here it needs to be (re)emphasised that this is not a sequential or linear process, i.e., as Deleuze and Guattari (1987) put it, "All three at once. Forces of chaos, territorial forces, cosmic forces: all of these confront each other and converge in the territorial refrain" (p. 312).

Based on the discussion above a new framing for the "old" conceptual model can be devised. A central idea is that chaos, and from it, order, can arise anywhere in the cosmos, i.e., all learners will not start their liminal journeys from the same position. Most learner journeys through the liminal space will begin in a state of chaos when learners fix their fragile centre points from which they will attempt to create ordered territories out of the chaos. These liminal territories can be imagined to stretch out from this chaos core and to overlap with and merge into each other to varying degrees. According to the phenomenographic tradition, the territories will be distinct from each other and finite in number. Most of the time the territories will be temporary and learners will dismantle them again when moving to new territories. Deleuze and Guattari (1987) refer to this as deterritorialization. The exception from this is when a learner—for one reason or another—gets stuck, unable to move forward. Deleuze and Guattari (1987) observe that "[a] territory is always en route to an at least potential deterritorialization [e.g., moving on toward new understandings], even though the new assemblage [content and expression] may operate a reterritorialization (something that 'has-the-value-of' home) [e.g., getting stuck (maybe due to an illusion of feeling safe)]" (p. 326). At some point learners hopefully break out from their last territory into the cosmos. If they then could look back at the "space" they had travelled through, they would see a "territorial flower" floating in the cosmic sea. At the centre is the chaos and out from it stretch overlapping liminal territories as the flower's petals. This is the re-imagined liminal space of the re-framed conceptual model of this dissertation. A visualisation can be seen in Figure 15. The territories represent conceptions or fragments of conceptions. Movement out toward the "flower's" edge parallels movement to more complex conceptions and breaking out into cosmos and looking back at the flower represent a new way of seeing and/or a more holistic understanding (one can see the whole flower not just one's current territory).

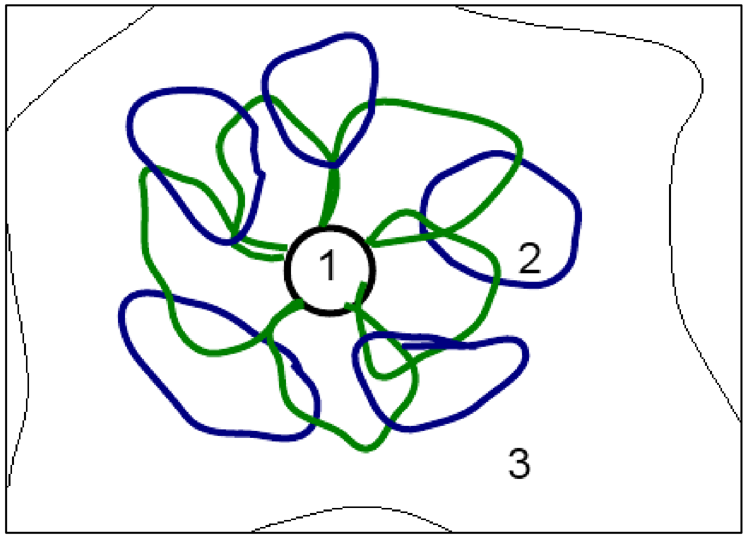

Figure 15: The new more non-linear conceptual model for liminal space—the territorial/liminal flower. The numbers have the following meaning: 1. Chaos, 2. Territories, 3. Cosmos

Based on Deleuze and Guattari's (1987) work, the phenomenographic idea of holding multiple conceptions simultaneously, and the TCT idea of oscillation, the claim can be made that learning clearly is non-linear in nature. In the re-imagined conceptual model the act of learning and navigating liminal space becomes a series of liminal territories learners will journey through on their way toward cosmos and these journeys might go in multiple directions and potentially involve much backtracking. In the end the hope is that most or all learners will break away from these liminal territories and join the cosmos. Lastly, drawing on Deleuze and Guattari, perhaps navigating a liminal space is more about changing one's rhythm than anything else.

To conclude, as the simple, yet elegant metaphor of the threshold is at the heart of threshold concept theory, Deleuze and Guattari's (1987) ideas appear to provide a fruitful metaphor for liminal space, which is worth to explore further.

Concluding Thoughts

In this chapter the different threads running through this dissertation have been drawn together. By comparing the outcome spaces for social justice of the three courses studied it was found that if the educational aim is for students to develop an articulated understanding of social justice then an explicit focus on social justice is preferable over addressing social justice implicitly through focus on other topics. However, at the same time, each course studied offered a robust approach for encouraging students to begin engaging in critical thinking. The conceptual model developed in this dissertation served the purpose of framing the research well, but by drawing on Deleuze and Guattari's (1987) work, the model can be further developed in term of non-linearity, which in turn might offer a fruitful metaphor for liminal space.

Chapter 9

Summary and Conclusions

As all good things must come to an end, in this chapter the exploration of the proposed social justice threshold is brought to a close with a summary of the project and some conclusions.

In the research project discussed in this dissertation it was recognised that problem solving is a central activity to engineering. However, it was also recognised that the conditions for doing engineering are changing, especially in light of pressing issues of poverty and environmental sustainability currently facing humanity, and as a consequence, engineering education needs to emphasise *problem definition* to a greater extent—i.e., why and how have these problems emerged and what can we do about them for the future? One approach for achieving this, explored in this dissertation, is through courses that explicitly relate engineering and social justice, or in a somewhat wider sense, courses aimed at developing critical thinking in relation to engineering. Since social justice is not something that has been traditionally emphasised in engineering education, it was hypothesised in this study that for many students, adoption of a critical perspective to their practice and profession will be experienced as alien and troublesome, but also has the potential of being transformative. In line with Meyer and Land's (2003, 2005) work on threshold concepts, social justice was proposed to be a threshold for students of engineering, and in a wider sense for the whole discipline of engineering. By studying the variation present among students in three different courses—*Sustainable Design Politics and Culture*; *Science, Technology, and Ethics*; and *Engineering and Social Justice*—the intention was to understand how students approach and internalise social justice as a perspective on engineering and/or develop their abilities to think critically. This dissertation is part of an educational effort aimed at helping prepare students for the challenges and opportunities they will face in their future careers in an increasingly globalised and changing world.

The Research Questions which Guided the Inquiry

How can students be encouraged to adopt a social justice lens toward their practice and profession?

While all three of the courses studied operated on a similar basic pedagogical model and appear to be successful in encouraging students to engage in critical thinking, it does seem that the particular constellation of the *Engineering and Social Justice* course facilitated well the students to pass through the threshold of "seeing through the lens of social justice." These included; a seminar style classroom; two instructors with open minded attitudes willing to critique themselves and each other; a small class size; active community-based group projects; interdisciplinary students; a continuous emphasis on critical thinking; and the flexible, as course instructor Richard Day puts it, "jazz" style of teaching.

What are the ways in which students vary in their approach to taking a socially just perspective to engineering?

An outcome space for social justice emerged for each of the three courses studied and a similar general trend that, can be described as moving from "Social justice as no understanding, misconceptions, or contradictions" to "Social justice as fragmented understanding and/or isolated characteristics" to "Social justice as helping and/or responsibility" to "Social justice as changing society" to finally "Social justice as a critical lens," could be discerned. However, of the three outcome spaces, the one tied to the course *Engineering and Social Justice,* contained the most well defined conceptions of social justice and displayed the biggest variation between conceptions. In total, nine different conceptions, clustered together into five liminal positions corresponding to the trend described above (see Figure 7 on page 127) were identified. A key characteristic that varies over the different conceptions is the students' awareness of the complexities surrounding social justice, which goes from simple and superficial to complex and deep. Other shifts are from passive to active and individual to collective.

What is the variation between courses that take slightly different approaches to a similar goal of encouraging students to develop their critical thinking abilities?

As mentioned above, all three courses studied appear to have been successful in encouraging students to engage in critical thinking, and while a similar trend was observed in each social justice outcome space, in most cases there was no direct correlation between liminal positions in the different outcome spaces, but rather there was overlap between multiple positions. Table 3, on page 236, shows an approximate comparison of liminal positions in the three outcome spaces.

One aspect worth noting is that that neither of the courses, *Sustainable Design Politics and Culture* (SDPC) nor *Science, Technology, and Ethics* (STE) gave rise to any liminal positions that are radically different from the positions and conceptions of social justice emerging from *Engineering and Social Justice* (E&SJ). Yes, they do offer slightly different framings and perspectives, but they offer no new significant themes. This indicates that a focus on sustainability or ethics (even in a wide macro-ethics way) does not, to any greater extent, add anything major to help engineering students understand social justice. However, it does appear to contribute a general awareness of social justice, at least if the course instructor has a personal interest in this area (but for one reason or another does not stress it in the classroom). Hence, it does appear that if engineering educators are interested in developing an articulated understanding of social justice in students then an explicit focus on social justice is preferable.

Also, SDPC and STE appear successful in their main objective of helping students develop critical thinking in relation to sustainable design respective macro-ethical perspectives on engineering.

Concluding Thoughts on the Conceptual Framing of the Study

In addition to contributing to the growing body of engineering education research, another outcome of this research project is a contribution to the emerging conceptual framework of threshold concepts and troublesome knowledge (e.g., Meyer & and Land, 2003, 2005, 2010), in the form of the two versions ("linear" and "non-linear") of the proposed liminal outcome space model shown in Figure 14 (on page 238) respective Figure 15 (on page 256). The initial conceptual model served the purpose of framing the research well, but could be further developed in terms of non-linearity by drawing on the work of Deleuze and Guattari's (1987) in order to create an intriguing metaphor for liminal space.

Chapter 10

Future Work

As the research project reported on in this dissertation has concluded and this document itself is about to be brought to a close, the question of whether there are any aspects of the research that can be further addressed or explored can be asked. Out of the discussion in Chapter 8 three areas of further inquiry emerge: 1. To draw on the findings of this study to create new content or practice for courses and study the impact; 2. To further develop the nonlinearity of the conceptual model by continue to draw inspiration from Deleuze and Guattari (1987); and 3. To explore the underpinnings of the threshold concept theory in relation to dominant disciplinary ways of thinking by drawing on the work of Foucault (1980).

Variation around Conceptions at Different Places in a Liminal Space

The main idea here would be to use the findings of this study, i.e., the three social justice outcome spaces, the outcome space for sustainability, or the emerging perception shifts of engineering depending on course context, as input into current and future pedagogical practices, by drawing on the variation theory of learning (Marton & Tsui, 2004), to use variation around conceptions of the phenomenon on question (e.g., engineering and social justice) at different places in the liminal space to help students to move through the threshold. As was reported in Chapter 7, this was done in a limited manner within the frame of the current project, but more study is needed in order to improve the exercise and evaluate its usefulness for students more thoroughly.

In terms of lessons learned regarding eventual redesign and development of the three courses studied, as has been discussed in Chapter 7, all three classes have a robust pedagogical model at their core, but some suggestions for further development can be made: In *Engineering* *and Social Justice*, because there was a tendency among student project groups to split their work down disciplinary lines, it would be advisable to effectively stress that both engineering and social science students engage with the full range of tasks involved in a project, in order to enhance their learning experience further.

In *Sustainable Design Politics and Culture*, as the students' case studies are a central part of the course and were appreciated by the students, it would be advisable to bring them in a bit earlier in the course and further tie them to the mechanism of the students picking their own readings and writing research updates in order to give these course elements further purpose and structure.

Because interdisciplinarity overall was perceived to be a beneficial element in the other courses, in *Science, Technology, and Ethics*, involving non-engineers in the class would to be a good idea (which the course instructor wants to do). Also, it would be advisable to integrate the students' case studies further into the classroom, for example, by asking students to discuss an earlier draft of their paper with peers during a class session.

Further Development of the Conceptual Model

The foundation for a more non-linear conceptual model of the adapted phenomenographic liminal space used in this research project was put forward in the Chapter 8. While the idea of mapping the different states of liminality (Meyer et al., 2008) onto Deleuze and Guattari's (1987) work in *A thousand Plateaus* appear to provide a fruitful metaphor for liminal space, this needs to be further explored. This work is in its planning stage.

Threshold Concepts through a Foucaultian Lens

A key part of how the threshold concept theory (TCT) has been developed focuses on the relationship between threshold concepts and the "accepted" ways of thinking in a discipline; for example, Davies and Mangan (2007) see threshold concepts in a discipline as a web of related concepts that partly reflects the historical development of thinking within the subject. In the light of the discussion of thought collectives within this dissertation and the indications that the "accepted" ways of thinking of a discipline can contribute to the creation of thresholds for the discipline in question, further investigation of the underpinnings of TCT might be a good idea. This will be done by applying a *Foucaultian* lens to the framework, since part of Foucault's (1980) scholarly project was aimed at understanding relations of power and discursive formations. This work is in its planning stage.

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Appendix I

Examples of Interview Guides

The questions that were used to generate discussion about social justice and engineering during the interviews and in the study of *Engineering and Social Justice* are presented below.

First round of interviews

General discussion of the class

What are your impressions of the class?

What do you feel is the purpose of the class?

What were your reasons for picking the class?

What is social justice to you? Can you define or frame it?

What is engineering to you?

What in your view controls engineering and technology?

What is the role of profit in relation to engineering?

What is in your opinion the relationship between social justice and engineering?

What would socially just engineering entail?

Focus on the group projects

What has the group done so far? What do you think about it?

How have the group structured the work?

How do you make this a social justice project?

What is the role of project in course?

Second round of interviews

What do you feel that you have learnt?

How has the course contributed to your understanding of social justice?

Has your understanding of social justice changed during the course? If so, in what ways?

What is social justice to you now?

What does socially just engineering mean to you?

How did you engage with the topics raised in the course—in and outside class?

Appendix II

Excerpt from an Interview Transcript

Below, an excerpt from a transcript from the first round of interviews in the study of *Engineering and Social Justice* is shown to illustrate how a discussion based on the questions in the previous section could evolve. The following notation has been used: Ier = interviewer and Iee = interviewee.

Ier: What is social justice to you? Define it? Frame it? What you just said?

Iee: I think that it is a bit more complicated as it relates to engineering, cause there is the, you know, teach a man to fish ... for the rest of his whole life, but with eng you can't really teach someone to do engineering, or be able to do those things. I think that social justice is, I guess, promoting a social change, in sort of helping out the society to grow itself instead of just throwing money at the situation.

Ier: How would you relate that to eng? Would engineers help building society?

Iee: Looking at countries that have very poor wastewater systems which causes disease and causes huge problems in a country. Having engineers come in and aid the city and the country with technology we already know about and we implement and is already out there, to kind of assist them, bring them up more to health standards we are on (inaudible) on issues like that. Helping them bring their knowledge as a county or city up to that level of understanding so that they can continue a sustainable infrastructure.

Ier: So the difference would be if we only went in and built?

Iee: If we went in and build a wastewater system for a city that would be kind of a charity thing. Going in and working with the country's what would be like ministry of transportation or ministry of environment for Canada, working with them to assist them in understanding of those matters and (inaudible) to help them bring their cities up to a liveable level.

Ier: So that would be more socially just?

Iee: That's the important part to help them to be able to run their own country, rather than us coming in and throwing in a water system or something like that, which is good in itself, but...

Ier: So you see do you see the term SJ in relation to engineering mostly on a global scale, or?

Iee: I think that it is at least on a large scale, just because engineering itself is kind of a large scale thing, like civil engineering, the things you are working, are going to be assisting on are wastewater systems, fresh water supply, large projects like that.

Ier: It is less let's build this little gadget here?

Iee: Yeah, it can be that too. ... It is almost as if you really only need to assist the government that runs a country, because you can't go in and help run the country, like it is up to the government of that country to run itself. And you are not going to have someone to come in like just start assisting Canada and running Canada. Canada needs to run itself and do things its way. I think it is national on that level where there needs to be the government of that country that's deciding to go on with any project it thinks is good.

Ier: You seem to be saying there are two aspects. First you are saying we can't just teach them something, at least not in relation to engineering that's it not enough, but on the other if we are going in and help them build something then we still have to teach them something, right?

Iee: Yeah.

Ier: So it is to get a bit of both then? To actually do something and then share knowledge is that what you are saying?

Iee: I think there are sort of two different levels of it, because ... whatever, it is third world or it is Canada, there is just the people in the city that might benefit from an engineering project or humanitarian whatever, right? But you are not actually going to teach them about this infrastructure system you have put in, because people in Kingston, in Canada, wouldn't understand anything you are talking about and it is all around them all the time. But the people who are the engineers of that country...

Ier: (inaudible)

Iee: ... teaching them...

Ier: So you would share with the people who have the skills and knowledge?

Iee: Exactly.

Ier: That's make sense.