Sacred Knowledge: How Does The Graduate Student In Engineering Innovate?

Tanya M. Vernon

This thesis is presented for the Degree of Doctor of Philosophy of Curtin University of Technology

August 2009
To the best of my knowledge and belief this thesis contains no material previously published by any other person except where due acknowledgement has been made. This thesis contains no material which has been accepted for the award of any other degree or diploma in any university.

Tanya M. Vernon
Date 18 August 2009
archetype [ar-ki-typ], a symbol, theme, setting, or character-type that recurs in different times and places in myth, literature, folklore, dreams, and rituals so frequently or prominently as to suggest (to certain speculative psychologists and critics) that it embodies some essential element of ‘universal’ human experience. Examples offered by the advocates of myth criticism include such recurrent symbols as the rose, the serpent, and the sun; common themes like love, death, and conflict; mythical settings like the paradisal garden; stock characters like the femme fatale, the hero, and the magician; and some basic patterns of action and plot such as the quest, the descent to the underworld, or the feud. The most fundamental of these patterns is often said to be that of death and rebirth, reflecting the natural cycle of the seasons: the Canadian critic Northrop Frye put forward an influential model of literature based on this proposition in Anatomy of Criticism (1957). Archetypal criticism originated in the early 20th century from the speculations of the British anthropologist J. G. Frazer in The Golden Bough (1890–1915)—a comparative study of mythologies—and from those of the Swiss psychologist C. G. Jung, who in the 1920s proposed that certain symbols in dreams and myths were residues of ancestral memory preserved in the collective unconscious. More recently, critics have been wary of the reductionism involved in the application of such unverified hypotheses to literary works, and more alert to the cultural differences that the archetypal approach often overlooks in its search for universals. http://www.answers.com/library/Literary+Dictionary-cid-4126
## I Introduction

1. No stories ......................................................................................................................... 7
   - Abstract .......................................................................................................................... 8
   - Acknowledgements ........................................................................................................ 9
   - Overview ......................................................................................................................... 10
   - Organisation .................................................................................................................. 11
   - Motivation ...................................................................................................................... 12
   - Archetype ....................................................................................................................... 13
   - Sacred Knowledge: How graduate students in engineering innovate ....................... 15
   - The Matrix and Research Process Flow Chart .......................................................... 16
   - Figure 1 Research matrix .............................................................................................. 17

   - Figure 2 Research Process Flow Chart ...................................................................... 18

2. Once, oh small children .................................................................................................. 20
   - Rationale ....................................................................................................................... 21
   - Literature Overview ..................................................................................................... 22
   - Literature: A detailed discussion ............................................................................... 25
   - Methods and Methodology .......................................................................................... 36
   - Moments ....................................................................................................................... 44
   - Validity ........................................................................................................................... 44

## III Analysis

3. The price of my stories .................................................................................................... 50
   - How is knowledge acquisition driven in a graduate engineering laboratory? .......... 52
     - One fine day: A day in the life of the laboratory ...................................................... 53
   - 3.1 Osebo ....................................................................................................................... 60
     - Osebo Introduction .................................................................................................... 60
     - Phenomenon 1 APPRENTICE LEARNING, Introduction ....................................... 65
     - Phenomenon 1 APPRENTICE LEARNING, Discussion ........................................... 73

   - 3.2 Mmboro ................................................................................................................... 77
     - Mmboro Introduction .................................................................................................. 77
     - Phenomenon 2 SOLVING TO SOLVE, Discussion ............................................... 84

   - Figure 3, N minus 1, pages 1 and 2 ............................................................................. 84

   - Figure 3a, N minus 1 Page three .................................................................................. 85

   - Phenomenon 3 CARE AND CONCERN Introduction ............................................... 87
   - Phenomenon 3 CARE AND CONCERN, Discussion 1 ............................................... 92
   - Phenomenon 3 CARE AND CONCERN, Discussion 2 ............................................. 96
   - Phenomenon 3 CARE AND CONCERN, Discussion 2 ............................................. 97
   - Phenomenon 3 CARE AND CONCERN, Discussion 2 ............................................. 98
   - Phenomenon 3 CARE AND CONCERN, Discussion 2 ............................................. 99
   - Phenomenon 4 VOLUNTARY INATTENTION Discussion .......................................... 105
   - Phenomenon 4 VOLUNTARY INATTENTION Discussion .......................................... 106

   - 3.3 Mmoatia .................................................................................................................. 109
     - Mmoatia Introduction .................................................................................................. 110
     - How are papers written in engineering? ................................................................. 113
     - What is the outcome of the process? ........................................................................ 113
     - Why are papers written? ......................................................................................... 114
     - For who is knowledge manufactured? ..................................................................... 116
   - Phenomenon 5 The Manufacture of Knowledge Discussion ..................................... 116
I Introduction
1. No stories

The African storyteller begins:

“We do not really mean, we do not really mean that what we are about to say is true. 
A Story, A Story; let it come, let it go.”
Abstract

In the beginning, there were no stories. This very basic statement is the core of all experiential learning. Experiential learning means learning by doing, learning in practice, or on-the-job experience. An experienced person, from master chef to commercial diver, is one with many many stories.

Submitted for the degree of doctorate of philosophy at Curtin University, this thesis seeks to provide a definition of innovation in the graduate engineering student case. This task has been accomplished via an intersubjective journey which did commence in a laboratory of Australian electronic engineers and ended in the innovative and fast paced oil and gas industry. The fundamental thesis question which guides the journey is: How does the graduate student in engineering innovate? Two subordinate questions provide signage for the quest: How is knowledge acquisition driven in a graduate engineering laboratory? and What is the nature and purpose of the PhD? The concept of quest or journey is a metanarrative of the storied lives of the researcher and researched. Major milestones include II Context which describes the landscape of the study. It includes a Rationale, a Literature review, Representation & theoretical framework, Method & methodology and Validity Criteria. The II Context section will provide the reader with two sets of criteria by which I suggest the thesis be judged: Academic and Literary. A second milestone is III Analysis where I share supervisor, student and innovation stories to consider five major phenomena: APPRENTICE LEARNING, SOLVING TO SOLVE, CARE AND CONCERN, VOLUNTARY INATTENTION, and MANUFACTURE OF KNOWLEDGE. The third milestone on my quest is IV Linkages which considers why the students are undertaking their quests. As oracle, I query the students: What is your most rewarding experience? What is your definition of engineering? and What is the most valuable skill you will take away from your experience? V Findings offers a definition of innovation with supporting discussions. VI Epilogue discusses an intersubjective method and methodology of research which lends new understanding to communities of practice and commercial innovation.
Acknowledgements

The people who made this thesis happen are numerous. All of the Pseudonym Lab gets credit for helping me learn about them and about me: Tom, Yasir, Dock, Safwan, Marvan, Saif, John, Goran, Brad, Zahir and Mark and their supervisors Heng Lee Hong Leung, Rajan Ali and Gabir Taza. I wish to thank Professor John Wallace who guided me through the thesis in the very best way a supervisor can, by attending to me and helping me make meaning in my thesis and my life. I also thank Dr Doug Myers for his early support and innovation stories. Thanks go to Veolia; guys, without support of my thesis, and importantly, showing me innovation in action, this thesis would not have launched. I especially thank Lance Birdsall and Mark Berge. You changed my life. You gave me a voice when I had none, you saw in me things I didn’t even see. I owe you deepest gratitude. Finally, I thank my mother and late father and especially my three children; Chris, Piet and Laurel, who wait patiently for me to grow up.
Overview

Once, oh small children
round my knee, there were no
stories on earth to
hear. All the stories belonged
to Nyame, the Sky God.
he kept them in a golden box
next to his Edwardal stool.

This thesis is a metanarrative, or story about stories. Using participant observation spanning thirty four full field days over a period of five months, and two sets of interviews with the same participants a year apart, some twenty interviews; I consider Australian examples of knowledge acquisition among a community of engineering PhD students. The overarching thesis question is: how does the graduate engineering student innovate? Two further questions bisect my coming to knowing about the students: How is knowledge acquisition driven in a graduate engineering laboratory? What is the nature and/or purpose of the PhD?

The field of research of the students is signal processing which is a subfield of electrical and electronic engineering. It uses mathematics to model, extract and transform information embedded in digital signals and is called digital signal processing. Utilising linear algebra and statistics, applications of digital signal processing include communications (i.e. mobile or defense), weather or economic forecasting, analysis and control of industrial processes, computer generated animation and image manipulation. Arguably, digital signal processing is one of the most powerful applications that will shape science and technology in the twenty-first century.


I utilise a literary style which presents charged data. As I move from polarities of archetype, as defined on the cover, to the fine detail of scripts transmitted to me, I hope to resolve in a dialectical way, conflicts enacted by the students and the master, researcher and researched, artistic and scientific, and traditional learning and intersubjective learning. As a meta-organisational tool, I use a simple parable—the story of Ananse, the spider man. Ananse comes from an oral tradition of African American storytelling. The book, _A Story, A Story_, was written in English as a children’s story in 1970 by Gale Haley. I borrow Ananse, the spider-man, to more easily show how I went about gathering my data. The (earlier) literary analogue of this tradition of “borrowing” is, for example, Walt Disney borrowing tales from the brothers Grimm to produce some of America’s classic animated films such as Cinderella and Snow White. Like Disney, I utilise archetypes in my narrative. The three archetypes introduced are: the leopard, Osebo, the hornets, Mmboro, and the fairy, Mmoatia. In terms of this thesis, Osebo represents the Supervisor, Mmboro, the engineering PhD students, and Mmoatia who represents illusive innovation. The quest, Ananse’s, the student’s, mine, is itself a
metanarrative, an archetype in and of itself, appearing in almost all literary traditions in every language. It is universal.

A word about gender is in order. This thesis was written about a laboratory of students and the Company in which I work. The absence of women in these discussions is not to write them out of the story of engineers. The absence of women is because the only woman in these discourses was me. I make no claims that the laboratory or my Company are representative of any other, and thus wish to preclude any discussion which suggest a perpetuation of stereotypes of exclusion of women from the realm of engineering, industry, or the studies of these.

Finally, all names, areas of research and other identifying material have been changed to maintain confidentiality of participants and areas of study. This extends to journals in which the students publish, conferences they attend and names of laboratories.

**Organisation**

The thesis is broadly arranged into five sections. The first section, Introduction grounds the research and contains prefatory material including abstract, acknowledgements, overview, organisation, motivation and three metaphors, herein referred to as archetype. It includes a matrix to assist the reader in following the sequence and my thought processes through each step of the research project, its motivation and thesis questions, and introductions to the representational and analytical themes. The second section, Context, contains an introduction and the following five sub-sections:

1. Rationale
2. Literature review
3. Theoretical framework & Representation
4. Method and methodology
5. Validity

The third section, Analysis, presents a number of stories which reflect phenomena arising from the data. It uses literary archetypes from *A Story, A Story* (Haley, 1970). The archetypes and corresponding literary references are:

- **Osebo** the leopard of the terrible teeth, represents the Supervisor
- **Mmbora** the hornets who sting like fire, represents the students
- **Mmoatia** the illusive fairy, represents innovation

In conjuring the lives of the supervisor, students, and myself pursuing innovation, I create an internal tension in the juxtaposition of the material scientific-ness of research context with the more creative and rich detail arising from the data and observations. In section four, IV Linkages, I aim to resolve this tension and that of emergent innovation dilemmas by returning the impetus to the thesis questions. The fifth section, V Findings, extends discussion of the original thesis question by suggesting a definition of graduate engineering innovation. VI Epilogue discusses an intersubjective method and methodology of research which lends new understanding to communities of practice and commercial innovation.
Motivation

The motivation for the study began many years back when I worked with engineers in a research centre. During that time I attended technical meetings and seminars, but understood little of the complex world of signal processing in which the electronic engineers worked. As they pursued $\Theta$ in the subspace of $Z$, I scratched my head in awe and just a bit of puzzlement. What drove them to work with algorithms, the fundamentals of math and physics, the physical constructs of a century of scientific thought? So is the beginning of many, many theses—the distinctly human capacity for wondering.

In attempting to answer the question of how a graduate electronic engineering student innovates there are a number of tacks one might take. Firstly, one might organise a nationwide survey of postgraduates, and/or supervisors and/or institutions. The survey instrument could be web-based, paper-based or via e-mail. The responses would be collated and analysed via SPSS. Correlation co-efficient and confidence intervals would be calculated and linkages drawn. This thesis is not that sort of study. Another approach might be to survey a smaller sample—perhaps a representative or random sample of students, supervisors or institutions. Following the survey one might then conduct interviews or focus groups. Survey data and interviews would then be analysed and again the linkages and results presented. This approach was not utilised in the study, although it was initially considered a viable option. A third and final approach might draw solely on interviews or focus groups from either random or representative samples. The latter model may be rigorous but is paradoxically decontextualised. An ideal model, in terms of validity and sufficiency as I later define, relies upon multiple methods, at least one of which must be deeply constructed in context. I therefore have relied upon the powerful nature of ethnography—that means to truly know something one must dwell in and on. I initially chose Kleinman’s flavour of ethnography as cited by Wolcott in *Ethnography: A way of seeing*:

> In order to build the scaffolding of scholarly materials that makes cultural analysis convincing and authorize the ethnographer to apply that analysis to different problems and special themes, the author composes an iterative process that goes back and forth across ethnographic context, social theory, and key issues. While coherence and analytic power count for something, so too do reflexive voice, style, thickly described ethnographic materials, and aperçus that illuminate a local world, often in order to challenge a putative universal...In place of our era’s egregious emphasis on minimalist interpretation, ethnography develops, meanders, even circles back it goes on and on. (Wolcott, 1999, p. 81)

It is from this epistemological dwelling point that I became a participant observer in the laboratory of student electronic engineers. From my observations and additional benchmarking exercises with innovators and institutions known for innovation, I later derived an interview questionnaire. As detailed in the methods section, I ultimately completed a longitudinal, ethnographically sufficient\(^1\) study of a cohort of graduate students and their supervisor over a three-year period.

From an early stage in the research, a number of scholars’ works proved useful: Latour, Knorr-Cetina, Salmon, Grant, Steiner and most importantly, Lave and Wenger. In Lave and Wenger’s *Situated Learning*, I found apprentice learning communities the most analogous

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\(^1\) While I initially adhered to the strict discipline code of ethnography, I later adopted a more naturalistic approach derived from Richardson (2000) and Jackson (1998). Early data collection was approached as rigorous fieldwork.
communities to graduate research engineers. Within that slim volume, Lave and Wenger note a study by Treweek (1988) where: “The reproduction cycles of the physicists’ community start much later, possibly only in graduate school. (1991, p. 100) Treweek’s study is one of a few studies of education which mention graduate students in the physical sciences. While there is some research in Australia of a) the graduate student body in general (mostly quantitative), b) students in the social sciences and c) humanities (mostly qualitative), precious little qualitative research has focused upon graduate student engineers. I did not detect a single ethnographic/longitudinal study at that time. Some possible reasons for this might be the general prejudice that laboratory based students fare better with respect to timely completions, supervisor relationships, etc., hence they do not further contribute to a debate at a national level which might be redressed by policy. Secondly, engineers rarely write about themselves, and especially not using qualitative data. Doing research, particularly for theory focused engineers with whom I worked, does not dwell within the same realm as subjective messiness of human relationships. Thirdly, it is somewhat difficult to access these sorts of communities, particularly where the students are working on commercial-in-confidence industry linked projects. However, while we might guess as to the reason for this gap, one thing is for certain, the tide of research focus on supervision and students in the social sciences and humanities is about to turn. The burden of an innovation economy upon us.

Archetype

Metaphor helps organise both the thinking of the researcher and the thinking of the reader. It can contribute to organising multi-method studies with multi-data sources and multi-points of view. In order to accomplish this, Richardson (2000) utilises the metaphor of crystal, Fraser (1999) applies grain size, Wildy (1999) views with lenses, and Wallace and Chou (2001) use view—long range, mid-range and close-up. Most of the metaphors deal with scale or magnitude. I wanted to utilise a concept which suggested more than scale or angle of repose. The idea I chose is archetype. I recognise that through archetypes, difficult concepts are more easily understood. Archetype (and metaphor) is more easily utilised when it is applied in situ rather than post hoc. So early in my writing, I asked myself about essence—What is it that you want to convey? What is the most important revelation arising from reams of data collected through hundreds of hours of interviews and observation? The fact I return to time and again is that I observed A Story, A Story in which human lives intersect with that of the Supervisor and a story in which I ultimately become an actor/character. Stories have a linear progression, a beginning, a middle, and an end. Thus, I suggest there is no better way to organise the thesis than within the rubric of a story and the archetypes suggested by A Story a Story. I have chosen an oral story written and illustrated in the 1970’s by Gail Haley. I first heard the story in its oral form in a literature unit I undertook in the early 90’s as part of my Masters Degree. The reader is requested to read the story aloud prior to commencing reading the thesis.

A Story, A Story is a deceptively simple parable originating from Africa. It tells a tale of a very small man, Ananse, who wishes for the gift of story. In order to obtain stories from the Sky God, Ananse must embark upon a dangerous journey, and archetypal quest, to find Osebo, the leopard-of-the-terrible teeth, Mmboro, the hornets that sting like fire, and Mmoatia, the fairy whom-men-never-see. Ananse ingeniously captures the illusive leopard, hornets and fairy and pays Nyame, the Sky God. Ananse is then heralded by nobles and rewarded with the gift of story. A Story, A Story, is found in the inside front cover and also reprinted in its entirety at important points within the thesis text. The three major analytical sections of the thesis are divided into Osebo, Mmboro and Mmoatia. They form three archetypes around which I discuss key elements of the laboratory I studied. The first archetype, Osebo,
represents the Supervisor, the second, Mmboro, represents the hive of students. The final section focuses upon innovation and is characterised by the illusive fairy, Mmoatia.

The Supervisor as archetype, Osebo, can be typified as all seeing, all knowing. He seems a protective, but yet cunning leopard, nurturing, caring for and taking pride in his laboratory of students. Osebo provides a focus of one phenomenon—APPRENTICE LEARNING. He ensures his apprentices are provided for during candidacy, get published and generally assists them in finding a position after the completion of the PhD. The students, as archetyped by Mmboro the hornets, can be thought of as a kind of hive, a collective. As such, I present numerous and even divergent stories of five students to illustrate three individual phenomena: SOLVING TO SOLVE, CARE AND CONCERN, and VOLUNTARY INATTENTION. They work together to produce what is required of them—ordered, timely, constructive. Mmoatia is the archetype of innovation—pulling knowledge acquisition yet just outside of the grasp of the students and I. As the researcher, I am the storyteller, but like Ananse, I am also the seeker of story. “Indeed, Ananse enters the story he tells and becomes the character his telling creates. Telling and living become one.” (Lasser, 1979, p. 5)
Sacred Knowledge: How graduate students in engineering innovate

Ananse, the Spider man, wanted
To buy the Sky God’s stories.
So he spun a web up to the sky.

The title of this thesis *Sacred Knowledge* reflects paradoxes imbedded in the pursuit of knowledge. Can any knowledge post-scientific revolution be sacred in any sense? Ananse, the spider man, though full of cleverness and wit, appealed to the Sky God for his gift of story. I present my stories and appeal to the academy to accept them, the students in my research appeal to peers for the acceptance of their algorithms. We refer to a higher authority, though we still trust that knowledge is not mystical or sacred, but scientific, empirically derived.

How can the students’ algorithms and my stories which I present about the Supervisor, the students and me be sacred? The laboratory happenings I recorded during my observation period—the Supervisor meetings, the student discussions, avoidances and performances and the flux of everyday life which can only be known by intimate contact, are the rhythmic rituals of the Supervisor and his students. Their derived written work—the conference proceedings and journal papers are scriptures manifest of a process, of the research ritual. I write the story of the scripture writers, I represent a chronicle of heretofore unwritten rituals and tacit knowledge arising from PhD canon. The telling of this story is driven by three fundamental thesis questions. The overarching thesis question of how does the graduate engineering student innovate? is broken down into two sub-questions—‘How is knowledge acquisition driven in a graduate engineering laboratory?’ and ‘What is the nature (or purpose) of the PhD?’ In pursuing these three questions, I am like Ananse, striving to attain the gift of story. It is thus that I begin to spin my web. Because I realise there is some complexity to my interweaving and metaphor, I prove a matrix (Figure 1 Research Matrix) in this section as a visual structuring to numerous elements of my thesis. It presents section headers, the literal sequence of events as they unfolded in the progression of my work, thesis questions, major literature references, moment, and even the criteria by which I suggest the thesis be assessed.

To explore this at the outset briefly is useful. The assessment criteria referent is Mulholland and Wallace (2003) *Strength, Sharing and Service* and Richardson (2000) *Writing as a method of inquiry*. Mulholland and Wallace observe: “When a narrative inquirer, acting as the instrument of research (Eisner 1991), retells another’s story, the inquirer’s ideas and values both structure and alter the narrative (Blumenfeld-Jones, 1995)”. This suggests the researcher’s role in being more than an armchair ethnographer. Indeed restorying as I apply it, is not as a kind of distancing from the data, but a multiple point of view—a view as co-created by the Supervisor, a view as co-created by the students and finally a view that is essentially autobiographical. In the case of the first criterion, truthfulness is indicated by a lengthy time spent in the field and that fulfilling the truthfulness criterion gives strength to knowledge claims. Primarily STRENGTH is achieved via the way the researcher conducts the study. Throughout the thesis, I am careful to chronicle how I undertook the work, the length of time in the field and the methods employed. The second set of criteria as discussed by Mulholland and Wallace, focuses on how well the reader is able to experience vicariously through the author; that experiences ‘match their own and those they have read about’. One technique to achieve such vraisemblance is thick description. In the SHARING criterion, I have gone to extensive pains not to essentialise the experience of any of us, but rather to dwell continually near the field experience or data from the participants. The final criteria, SERVICE, considers the utility—“...a social experience in which the researcher assists other to construct knowledge by describing a case in such a way that the reader makes useful comparisons.”
To this aim, I have tried to chronicle, for example, how one can learn to be innovative, to move from known fields of expertise to those unknown. I demonstrate how I moved from a research based academic culture to industry.

The Matrix and Research Process Flow Chart

The thesis organisation matrix is a graphical aid for the reader to map the questions, processes, moments, methods and quality criteria to thesis sections for the knowledge claims I make. Please refer to the matrix following. It supplements the table of contents and provides a smaller paper-based site map to the thesis. Note the moments of the thesis, explained more thoroughly in the Introduction and literature review sections, and the quality criteria and how these are shaded to indicate how the moments and criteria have a temporal quality. This means that they extend over questions and sections and are not necessarily as discreet as I have made them. Also, the moments and criteria were not conscious a priori categories that I moved from as I undertook my research. As Mulholland and Wallace note:

Our decision to use this framework was made after initial case studies were written and analysed. We did not consciously gather our data with this framework in mind but chose it for its ability to assist us in thinking about what we knew and had written about the learning of science in a more interpretative way. (Mulholland & Wallace, 2003, p. 7)

While the matrix maps the moments, thesis questions, and quality criteria to the sections, I have also produced a flow chart to give an indication of how the data were collected and organised. This flow chart (Figure 2 Research Process Flow Chart) presents, in a graphical way, the manner in which I undertook major sections of completing the thesis, and highlights the temporal dimension. In this way, I provide the reader two styles—an interpretive/narrative style which arises from interviews themselves and a more structured view which arises from tightly organised chapters and moments.
<table>
<thead>
<tr>
<th>Section</th>
<th>Title</th>
<th>Headings</th>
<th>Moment</th>
<th>Question(s)</th>
<th>Literature (selected)</th>
<th>Methods</th>
<th>Contribution</th>
<th>Academic Assessment Criteria*</th>
</tr>
</thead>
<tbody>
<tr>
<td>II</td>
<td>Once, oh small children</td>
<td>Rationale, Literature review, theoretical framework, method &amp; methodology, validity criteria</td>
<td>First</td>
<td>Supporting material</td>
<td>Grounded Theory →Ethnography, Observation, Interviews (2003-2004), Benchmarking</td>
<td>Sufficiently ethnographic, introduce intersubjectivity</td>
<td>Strength</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>The price of my stories</td>
<td>Osebo--the art of Supervision, Mbombo--the hive of students, Mmoatia--truculent innovation</td>
<td>Second</td>
<td>How is knowledge acquisition driven in the laboratory?</td>
<td>Vygotsky, Mulholland &amp; Wallace, Knorr-Cetina, Jackson, Steiner</td>
<td>Interview, Weblog, Storying, Analytic induction</td>
<td>Voluntary inattention</td>
<td>Sharing</td>
</tr>
<tr>
<td>IV</td>
<td>So small, so small</td>
<td>Most rewarding student experience, defining us, fundamental skill</td>
<td>Third</td>
<td>What is the nature of the PhD? Most rewarding experience? Define engineering? Most valuable skill?</td>
<td>Jackson, Schon Mulholland &amp; Wallace,</td>
<td>Interview</td>
<td>Knowledge acquisition model Defining innovation in graduate study</td>
<td>Service</td>
</tr>
<tr>
<td>V</td>
<td>If it be sweet</td>
<td>How graduate engineer innovate?</td>
<td>Fourth</td>
<td>Define innovation. Zones of Development Does CoP work in industry?</td>
<td>Vernon</td>
<td>Intersubjectivity</td>
<td>Translational dialog</td>
<td>Service</td>
</tr>
<tr>
<td>VI</td>
<td>Conclusion</td>
<td>Commercial innovation and the anthropological project Intersubjective journeying Learning commercial innovation intersubjectively</td>
<td>Final</td>
<td>What are the contributions of the thesis? Have you sufficed the academic and literary criteria which have been suggested?</td>
<td>Jackson</td>
<td>Intersubjectivity</td>
<td>Intersubjectivity as research method</td>
<td>Service</td>
</tr>
</tbody>
</table>

*Literary criteria of mixed genres, polyvocality, descriptive device, point of view, pace, tone, and time are evidenced throughout!
Figure 2 Research Process Flow Chart

1. Observe students, May-August 2003
2. Record data, literature search on innovation
3. Write questions, conduct interviews, Oct-Dec 2003
4. Analyse data via 'writing as a method of inquiry'
5. Literature search on postgraduate study & policy
6. Revise question set, conduct second interviews, Dec 2004
7. Analyse data in light of inquiry
8. Utilise data for publications (6)
9. Themes defined, Data 'coded'
10. Utilise blog to check themes & conclusions, December 2005
11. Writing as inquiry: Interdisciplinary Method 2006-09
12. Thesis

Page 18
II Context
2. Once, oh small children

When the Sky God heard what Ananse wanted, he laughed: “Twe, twe, twe.
The price of my stories is that you bring me Osebo the leopard of the terrible-teeth, Mmboro the hornet who-stings-like-fire, and Mmoatia the fairy whom-men-never-see.”

The second section II Context has five sub-sections—Rationale, Literature review, Theoretical Framework and Representation, Method and Methodology, and Validity—which make clear all of the research and methods I undertook in my study. Given the breadth of the concept innovation, I am certain I have missed much in terms of scope. For example, I particularly focus on the Australian case and as such, focus on graduate study in Australia and to a lesser degree, innovation. While my methods and methodology may be applied anywhere, they initially were only applied in a laboratory of graduate students in an Australian University. The academic quality criteria upon which I wish to be judged are taken from Mulholland and Wallace (2003). “Strength, Sharing and Service: restorying and the legitimation of research texts” from British Educational Research Journal. While I discuss the quality criteria at length in this section under Validity Criteria I highlight it here so the readers’ attention will be drawn to the fact that section II Context itself demonstrates the STRENGTH criterion where I a) spent considerable time in the field, b) intended from the outset and do use multiple data sources; observation, interview, and personal experience narrative c) am careful to document my subjectivity and d) offer limitations of my study. These components contribute to the STRENGTH criterion as detailed by Mulholland and Wallace (p. 7-8). Literary quality criteria will also be discussed.

I commence the second section II Context with the Rationale sub-section which seeks to further elucidate the three thesis questions which form the basis for the study. The Literature Review covers several literature types: Commonwealth government documents, Business and management, Engineering, Technology and innovation, Social studies of science, Graduate student pedagogy, Narrative, Theory, Method & methodology. The Theoretical Framework and Representation sub-sections present my particular approach to literary and representational qualities I wish to instill in the outcome or representation of my thinking. The sub-section on research Methods and Methodology discusses the multi-method approach I took in order to insure both the quality and quantity of data. In the final sub-section of the II Context section, Validity, I more fully discuss the quality criteria, both academic and literary, by which the contributions of this thesis are to be judged.
Rationale

By way of introduction, I hope to provide a brief overview of the major research or thesis questions which serve as rationale for the study. The major questions are:

1. How does the graduate student in engineering innovate?

In bisecting this first thesis question, two separate thesis questions are further identified:

2. How is knowledge acquisition driven in a graduate engineering laboratory?

3. What is the nature (or purpose) of PhD?

Please consider the following as a brief introduction to each of the thesis questions.

How does the graduate student in engineering innovate? More than any decade, this decade, and maybe this century (as time will tell), society seems concerned with the business of innovation. Until now, invention and its child, technology, have been allowed to grow and flourish at a relatively organic pace. Now, somehow, technology is driven, catalysed by government and private think tanks and it is called innovation. It is not that technology itself didn’t exist, it is merely that everyone wasn’t talking about it, demanding each and every product from shampoo to satellite telephones be innovative. The word itself suggests movement–activity, action. It suggests design, and despite marketing campaigns aimed at millions of people, the imprimatur innovative somehow suggests someone has catered for the individual needs of the user. Implicitly, innovation suggests moral goodness. However, the word innovation is a hyponym². It evokes a meaning which is far bigger and more meaningful than the original literal meaning. Innovation in the basic sense is nothing more than the commercial realisation of an idea.

Though I felt fairly sure I knew who innovation was when I met her, very early in the PhD I embarked upon a search of innovative engineering practice and people. How does the graduate engineering student innovate? In focusing on this question early and frequently during the study, I felt certain I would not miss the Eureka! moment in my fieldwork when a student leapt from their seat with an enticing algorithm. Commercial innovation was not the focus of the thesis. However, I do return the discussion to commercial innovation at the thesis’ end, for to see innovation we can come to know her.

How is knowledge acquisition driven in the laboratory? Data seem to indicate that graduate students have several sites of experience which involve knowledge acquisition. The sites appear to form a system interface where the student can act or be acted upon. Each of the sites can be classed as learning ecologies (Business and Higher Education Round Table, 2006), where each Ecology is both independent but also interdependent upon the others. I refer to the three ecologies which emerge from the data as: the Network Ecology, Social Ecology, Knowledge Ecology. Section three III Analysis The price of my stories explores several views of the laboratory which represent five key phenomena. The phenomena typify events in the Ecologies model I propose as the Graduate Engineering Knowledge Acquisition Model (GEKAM). The model illustrates the learning process and attempts to answer “How”? is knowledge acquisition driven in the laboratory?

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² Hyponym is an invented word. Essentially it is a word or phrase which suggests something more than it actually is. ASAP, hype, innovation.
What is the nature (or purpose) of the PhD? In considering the previous section three III Analysis, several additional questions come to mind. Why undertake a thesis? What is the purpose? The fourth section of the thesis IV Linkages entitled So small, so small, so small discusses the GE-KAM and focuses on answering these questions to get at the fundamental nature and outcome of the thesis. The nature of the thesis can also be thought of as the output or accomplishment of a thesis. In this section I consider several questions to determine varied meanings of purpose and scope of the thesis as viewed by the Supervisor, students, and researcher. Only after I have analysed the purpose of the thesis am I able to return to the question of defining innovation in graduate engineering practice.

Literature Overview

Overview. This study is indebted to and informed by multiple textualities. Beginning with personal e-mail communication, to a blog, to modern literature, to the scriptures of the inventive ones and Commonwealth policy of to-day, a myriad of documents has supported the knowledge claims I make herein. While my database consists of more than 200 references, the actual number of texts one draws upon in the course of embarking upon, collecting data, analysing and writing a thesis is certainly double the number of recorded references. Given this, my literature review is but a small sparkling constellation in the night sky array of literature any particular researcher might also map. Much of what is revealed here depends upon the declination, distance, time of day, season—the map evolutionary and expanding. There are brilliant stars of the research, the light of which pervades each page. Some stars are smaller and less influential and some are barely recognisable to the untrained eye. There are seven classes or categories of stars that construct the constellation at the point when this thesis is written. The cross-disciplinary nature of the study has dictated the necessity of such an array of literary types. This contributes to the validity criteria, as does the recognition of moment in which the type fluoresces within the study. The validity criteria contributes to the strength criteria such that the reader can be aware of that the research in a cross disciplinary research project is far more complex than in straight science.

Literature types

Australian Commonwealth Government documents
Business & Management
Engineering, technology & innovation
Social studies of science
Graduate student pedagogy
Narrative, including both fiction and non-fiction
Theory, method & methodology

In this introduction to the literature section, I give a brief overview of each literature type and provide a key example. Following this, I position the focus of the literature review upon five of the categories; providing thorough descriptions and analysis. I further consider narrative and theory, method & methodology in other sections of the II Context; namely the framework, methods and validity sections.

As discussed in the previous section Rationale, the thesis has four moments or points in its evolutionary life. The first moment centres upon innovation and technology. The second moment centers upon graduate student pedagogy, including matters relating to the position of student and supervisor, and the third moment centres upon analysis. The fourth moment re-considers ethnographic research in the context of adult learning and innovation. Part of the literature, therefore, has moments of brilliance where it is fore grounded, but later declines.
For example, the business, management, and innovation literature shone brilliantly in the first moment of the thesis. The graduate student pedagogy and Commonwealth documents associated with postgraduate students and supervision effloresced during the second moment. In the third moment, I relied heavily upon social studies of science, narrative and theory types of literature. In the fourth moment, I relied upon my personal experience, my writing and Michael Jackson. As noted before, however, there are some sacred texts or everlasting stars which appear throughout all of the moments of the thesis. These enduring texts shall be quite evident.

**Australian Commonwealth Government documents** and reports inform the thesis throughout, taking prominence in the first and more importantly second moments, but appearing even in the third moment. A prime example of this type of document is, for example, the Research Quality Framework (RQF)(Commonwealth of Australia, 2005), report of the expert advisory group. The RQF report was the culmination of a year of study within the Australian context of research endeavours in Australian Universities. In the Higher Education Sector it received much media coverage, the outcome of which may have had the potential to change the way research and subsequent research student education was funded in Australia. Hence, it was an important issue to maintain as a watching brief. However, coincident with the release of the report was a change of Ministers of Education and thus, a potential shift in policy focus. Many Australian Commonwealth documents produced by advisory groups must be interpreted within this framework (i.e. important but perhaps transitory!) As is happens, the RQF was implemented and subsequently rejected under Labor government control. The Commonwealth also commissions reports via the Department of Education, Science and Technology, a prime example is Mark Sinclair’s Pedagogy of Good PhD Supervision (Sinclair, 2004). Each of these issue focused and intended to inform Commonwealth policy. In the first moment of my research, the utilisation of Commonwealth documents was somewhat problematic as I was considering technological innovation, which fell within the industry portfolio (Department of Industry, Science & Resources). Subsequently, and roughly coincident with the then Minister David Kemp’s white paper on Education, science and technology were moved to the education portfolio. Then, science and technology resided in the Department of Innovation, Industry, Science and Research portfolio (from December 2007). Included in this category are Australian Bureau of Statistics documents produced quarterly. In short, the education and innovation portfolios are both high priority for the Australian government, but don’t always end up in the same portfolio. Australian Commonwealth documents were primarily used in the first moment of my research where I sought to determine the amount of investment in research and development by higher education, an indicator known as HIRD, and in business, known as BIRD. Regardless of the above, each of the two governments for the last decade has focused on Innovation. The Howard government promoted innovation through Backing Australia’s Ability, and the Rudd Government is noted for its recent *Powering Ideas: An innovation agenda for the 21st Century* document. Imbuing innovation with efficacy was not merely a 90’s fade, the burden of the innovation economy is upon Australia. Harnessing, driving, focusing and using Australia’s innovation capital, in universities and business, has only just begun for Australia.

**Management and innovation literature** includes business and management types of articles and books which I perused in the first moment of my research. Primarily, I utilised them to explore business drivers for innovation and input to and from research and development. A prime example of this type of literature is Dodgsons’ (2000) *Management Of Technological Innovation*. Tangentially, I was interested in phenomenon of cringe—that of academia cringing at the face of business and equally, industrial cringe of academia. This
largely remains a question at large, and not within the purview of this research. Closely related to this category is the ‘engineering and technology’ literature source.

**Engineering and technology literature** is written for lay people by engineers, this genre of literature is perhaps one of the most accessible types generally available to the public. Commonly the books give detailed accounts of invention or engineering which effect daily lives. An important example of this genre is Vincenti’s (1990) *What Engineer’s Know And How They Know It* which is a delightful chronicle of the birth of aeronautical engineering. Perhaps the most endearing aspect of this genre is a generally direct engineering approach to engineering as a phenomenon. Predictably, they make no claims as to why engineers engineer, a question I hope to address herein. I made particular use of these books in the first moment of my research project.

**Social studies of science** literature is a genre of literature to which the thesis is perhaps the most indebted. The early example of this type is the work of Knorr-Cetina (1981, 1999), whose book *The Manufacture Of Knowledge* is an enduring star and informed the thesis throughout all of the moments. It is through the social aspect that we can explore the why? question noted above. Knorr-Cetina’s book informed my early thinking about was happening in the laboratory on a daily basis. Her work led me to sacred texts of social studies of innovation in Australia. Several key referents are discussed more fully below.

**Graduate student pedagogy** literature was only used in the second moment of my research, I generally found this genre of literature study to be both accessible and available from a number of points of view, that is to say, there are Commonwealth government documents focused solely on the subject, as already noted, there are social studies of students such as Salmon’s (1992) *Achieving a PhD*, and a collection of readily available academic scholarship on supervision. In the second moment of the research I undertook an extensive survey of Australian Higher Education institution policy and practices in graduate study. This benchmarking exercise brought light upon a sub-class of literature in the genre which seeks to interpret Australian Government policy at the institutional level and seeks to provide models for best practice, particularly in the area of supervision.

The **Narrative** category encompasses both narrative used as a research method, and narrative/story itself, for to write narrative inquiry, one must indeed read narrative! I first began writing about my research early in 2004 and an influential text became Laurel Richardson’s (2000) *Writing, A Method Of Inquiry* (see also Literary Quality Criteria). The work of Peter Carey, the Australian novelist, informs my ‘writerly style’ if I can claim one. Narrative genres and the notion of story have informed, indeed presided over the thesis from the second moment.

The **Theory, method & methodology** literature base is the firmament, the celestial sphere upon which are etched the constellation of texts. Without theory, method and methodology there is no substantiation or basis for beginning or end. An important beginning, and monograph whose themes of situated learning and communities of practice are pervasive throughout the thesis, is the slim volume by Lave and Wenger (1991) *Situated Learning*. Also important is Wenger, Jackson and Richardson. Perhaps needless to say, these texts which are the firmament are present at all moments of the thesis.
Literature: A detailed discussion

As noted previously, the bases of knowledge claims within this thesis are supported by a multi-disciplinary admixture of seven categories summarised above and typified by the various chapters, documents and books cited. The following section expands the discussion by careful consideration of five of the seven categories: Commonwealth government documents, Management and innovation, Engineering & technology, Social studies of science and Graduate student pedagogy.

Australian Commonwealth Government documents

As noted above, Commonwealth Government documents are a rich source of information which I used early on in my research, but continued to access throughout the study as I wanted to maintain knowledge of the trends in higher degree (graduate student) education in Australia. The Commonwealth makes most of the documents widely available at Australian Government sites by Portfolio: www.australia.gov.au/Government_Sites_by_Portfolio. The documents normally are key sources for statistical information about research, students and other quantitative data relating to science and technology. Reports such as the Department of Education, Science and Training (DEST) performance indicator documents (Commonwealth Department of Education Science & Training, 2004a, 2004b) and Australian Bureau of Statistics reports research and knowledge metrics (Australian Bureau of Statistics, 2000, 2002). The notion of innovation was high on the Commonwealth agenda from the mid 1990’s onward, and a key tenant of the initiatives was to link industry with public sector research and development, for example see: (Department of Industry Science and Resources, 1998) 1999 document What a good idea (Australian Research Council et al., 1999) depicts in layman’s terms the benefit of linkages. Following closely in this vein, the then Chief Scientist, Dr Robin Batterham, (2000) issued his important Chance to change. As a Rio Tinto CEO, Dr Batterham personified the linkage of industry to public sector research. Following closely in the wake of Batterham, the Australian Research Council (Australian Research Council, 2000; Australian Research Council, CSIRO, & National Health and Medical Research Council, 2002) introduced commercialisation to the momentum inspired by Batterham. Commonwealth advisory groups, such as the Australian Vice-Chancellors Committee (2002) and the Prime Ministers Science, Engineering and Innovation Council (Prime Minister’s Science Engineering and Innovation Council, 1998, 2000, 2001) linked University based research to the commercialisation train. Commissioned reports focusing on this exact subject proliferate in this period, but as these are at arm’s length from the Commonwealth and as such, they are treated in the Business, management and innovation section below.

In the early part of the decade, I managed an education program in one of the flagship high technology research centres in Australia—a Cooperative Research Centre. The centre, which had several commercial spin-off companies, aimed to link research in higher education with industry users of technology. It has been my pleasure to hear Dr Batterham, heads of the Australian Research Council and National Health and Medical Research Council (peak research funding bodies in Australia) speak and to meet several ministers. The real joy of my work was dealing with graduate students however, and it was from this milieu that I actually became interested in the topic which became the thesis question.

Early in 2001, Australia’s then prime minister, John Howard released a position paper Backing Australia’s Ability (2001) and major funding for several centres focusing on technology. Since this time two world class centres, one in the area of biotechnology and one
in information and communications, have been established. While a real return on investment has yet to be seen, the available research funding to academics working in the areas of biotech and ICT has fallen sharply as funding is channeled to the national centres. The hyperbole surrounding innovation is in the forefront of public discussion with creation of the Australian Government Innovation, Industry, Science and Research portfolio in 2007. The foregrounding of innovation and inclusion of science and research in the portfolio is tangible recognition of the focus of Australia’s interest in return on investment in these areas. Innovation remains high on the agenda into 2009, as evidenced by the issuing of Powering ideas: an innovation agenda for the 21st century (2009) which encourages (p. 5) Measures to renew and expand Australia’s publicly-funded research workforce, research infrastructure, and machinery for sharing research results that will yield high returns.

Management and innovation literature

The business, management and innovation literature were explored widely in the first moment of my research program. As noted in the preface to this section, I primarily used innovation and technology literature (detailed below) to confirm assumptions I had about what innovation in technology looked like. I had to be certain I knew what it was before I found it. Much of the business and management literature lies in either of two categories, case study, or history of...A sub-category—textbook, is comprised of case study and history. Dodgson (2000) became an important referent, as did Faulkner (Faulkner, 1998, 2000), who also writes about engineering. Obviously, I was also interested in university innovation in Australia. Turpin (2000a, 2000b; 1999) and with Pol (1999) write in this vein, as does Mendes (2002), Rogers (1998) and Roberts (1988). Marceau (1994) writes particularly powerfully that a requirement for innovation to happen, industry must become a consumer of the technology produced by universities, and that all of the complexes below work to the full extent possible with the others.

Public sector research organisations,
Regulators ie governments of all levels,
Producers ie firms,
Users ie consumers, usually other firms.

Marceau’s work is as prescient today as it was a decade ago, perhaps more so because major telecommunications industries, the main employer of research students in this area of electronic engineering, have moved research and other operations out of Australia at an increasing rate. Furman (2002) similarly postulates three determinants of innovative capacity: the knowledge base and higher education as contributors to the innovative infrastructure, a country’s industrial complexes and clusters in National Innovation Systems (NIS) and linkages between Commonwealth innovation infrastructure, of which higher education is but one component, and clusters (Vernon, 2003). Research management is a small but important sub-category, and in this Burgio-Ficca (2001) and Roberts (1988) are important contributors.

Engineering and technology

I undertook literature searches in engineering and technology immediately after working with the concepts of innovation in higher education. In moving from innovation in higher education to engineering and technology research, I was scaffolding my newly gained innovation knowledge to embrace a more narrow and purposeful search of how the business of engineering translates to technology. In this search, my supervisor, Dr Myers was extremely helpful and suggested a number of sources which proved valuable throughout my thesis work.
The first book I read for the thesis was Kidder’s *The soul of the new machine* --a compelling story of the first 32 bit processor, and the visions Kidder conjures are etched permanently in my memory. Buccarelli (1994) and Blainey (1971) are important monographs relating to engineering and Australian technology which guided my early research. An equally important monograph by Vincenti (1990) allows us rare glimpses into the manufacture of technology by aerospace engineers. I have utilised Vincenti concepts to today. Ferguson (1977, 1993) also provides insight into engineering psyche, particularly focusing on ability to visualise working machines in the mind’s eye. Alternatively, Freeman (1994) and David (1995) consider economic aspects of technological change, whereas Basalla’s (1988) monograph assesses societal impact of technology. A journal article entitled Educating for innovation and management: the engineering educators’ dilemma in the *IEEE Transactions on Education* led me to the work of Dr Carol Steiner. Dr Steiner’s research embraces most major themes of my research, namely; qualitative study of engineers, primary focus on innovation; Australian-based study and work in high technology organisation. Her PhD thesis, *Magic moments* (Steiner, 1995) is a key referent for my PhD study.

**Social studies of science**

As I pursued innovation, particularly innovation among graduate students, my supervisor, John Wallace drew my attention to the monograph *Laboratory life*. Latour and Woolgar made it their business to follow scientists around, as did Knorr-Cetina for the later book—*The Manufacture of Knowledge*. Latour (1987; 1986) and Knorr-Cetina (1981, 1999) provided the impetus for me to follow students around—record their activities, observe their rituals, inscription machines and chronicle how they construct knowledge in engineering. As discussed, Carol Steiner’s thesis *Magic moments* (Steiner, 1995) is another key model for my study. Her thesis is a phenomenological study of innovation within a firm of engineers/innovators in a high-technology research and development company in Australia. Essentially, Steiner and I work from the same question—why? and we approach the problem from a constructivist frame. But her phenomenological study is conceptualised through Heidigger’s concepts of daesin. Whereas my study commenced as ethnography and via dialectical discourse, became an intersubjective (Jackson, 1998) thesis. One important difference between Steiner’s thesis and my own, is not the subtlety of theoretical frameworks, but the fact that I work with apprentice research engineers, the likes of whom are, upon graduation are occasionally hired by the sort of innovation firm Steiner studied. The difference, I suggest, is one of being and becoming. My study works in the area of becoming—all that entails to prepare for being. Her study dwells fully within the realm of being, of daesin. To be clear, the phenomenological study considers one phenomenon—innovation, very well. My thesis begins with the beginning—the noviate innovator, and hopes to dwell in all that facilitates learning how to be innovative. My study, originally grounded pure ethnography, took the frame of intersubjectivity as I became immersed in the work of the laboratory over the three years I studied the students, their constructs and tracked their careers. For this, Jackson provides an analogy:

Put otherwise, the task of ethnography is not to know the Other in any final sense nor even to know the self through the other. Nor is it to change the lives of others, or even to critique one’s own culture. Its warrant and worth lie in its power to describe in depth and detail the dynamics of intersubjective life under a variety of cultural conditions in the hope that one may thereby be led to an understanding of how those rare moments of erasure and effacement occur when self and other are constituted in mutuality and acceptance rather than violence and contempt. (Jackson, 1998, p. 208)
Jackson suggests we don’t hold anything constant: neither language or gender or ethnicity. To do so is to ignore the very fabric or stuff of humans—the need to feel ‘that he or she has some say over his or her own life...that his or her presence alters the way world is constituted’ (Jackson, 1998, p. 209). In terms of the social study of science (as other?) the work of both Hacking (2002) and Pickering (1995) were consulted and some notions in this thesis arise indirectly from their approaches. I came upon Ashmore’s work (1989) late in thesis writing.

Graduate student pedagogy

The second moment of my research is heralded by a shift in the focus of my research from the business of innovation to the activity of student apprenticeship. This shift occurred after I first began writing about life in the laboratory of students. Shortly thereafter, my principal supervisor took a leave of absence and supervisory issues took on new meaning. The literature in the area of graduate student supervision is vast, and consists of at least four subcategories or genres:

a) trauma literature—qualitative, primarily focused in humanities and social sciences
b) improvement imperative—primarily focused at supervisors and institutions
c) How to ... guides focusing on method, management, manuscript and
d) Reports—primarily quantitative.


Trauma literature provides interesting points of comparison with the work undertaken in this study. The authors Grant, Lee and also Knowles (1999, 2001) do not work with students in laboratory based disciplines. A discipline bias for research involving social sciences and humanities may be a result of the earlier writing of Moses (1988), who suggests that laboratory-based students are relatively sheltered from impacts which may affect the solitary researcher in the humanities (see also Deem & Brehony, 2000; Whittle, 1992). Alternatively, as suggested previously, the bias may be the result of inaccessibility to co-horts or lack of interest of engineers to write about themselves in a qualitative way. Importantly, engineers tend not to support research which appears ‘soft’, unfounded on statistical data or otherwise empirically derived. It is likely that narrative research, for engineers at least, equates to harlequin romance novels.

Various How to...guides are process oriented and contribute little to theorising in postgraduate issues, however a significant number of governmental, association and commissioned reports which are readily available at Commonwealth and Australian university web sites, do have the capacity to contribute to continued dialogue about graduate policy. The reports draw upon survey data of Australian students and/or supervisors and rely on the rigours of statistics for conclusions. Two examples are the Postgraduate Research Experience Questionnaire (Graduate Careers Council of Australia & Australian Council for Educational Research, [2002]) and Baker’s analysis of the Australian Postgraduate Award scheme (Baker, Robertson, & Toguchi, 1997). This genre can also contain benchmarking elements and the usual focus is to affect Commonwealth policy or illustrate best practice. A failing of this genre of research is the significant lag between collection of the data and presentation of the report.
Also, much of the information is de-identified, making it nearly valueless for institutions to improve. More importantly from the point of view of my study, is my experience that engineering students who leave graduate study tend to normalise the experience of achieving the PhD within months of graduation and are usually dismissive of negative experiences when surveyed about the research process. This might mean they are generally satisfied, do not respond to surveys or are less willing to discuss the relationship than their humanities and social science counterparts. In fact, the Supervisor is still in a position of power over the student until the student has become a fully-fledged part of a new, professional community, so it is my belief they would be reluctant to risk career prospects.

Included in the report genre are statistics based papers written by individuals / academics, rather than government or government associations. One such report is Kam’s (1997) *Style and quality in research supervision: The supervisor dependency factor*. This article, written with data from a survey of postgraduate students at RMIT University, fixes a number of variables upon which pivot the enigma of supervisor satisfaction. Kam includes students in engineering and science in her survey, and unsurprisingly for my research, suggests engineering students are relatively supervisor dependant. She is one of few Australian-based scholars who have dealt with graduate student engineering pedagogy. Haksever and Manisali (2000) undertake a survey of research students, but in the UK and in the discipline of construction management. Delamont, Coffey and Atkinson (2000) note the dearth of qualitative educational research in higher education, with their own work *Critical mass and pedagogic continuity: studies in academic habitus* (Delamont, Parry, & Atkinson, 1997) a notable exception.

**Narrative**

I began working with narrative in the second moment of the research study. This was primarily due to an interest in narrative research I developed when I took a graduate unit on constructivism. After reading Richardson’s (2000) *Writing a method of inquiry*, I fully embraced this methodology and from that point forward her ideas framed all my later research endeavours. Narrative writing is supported by scholars who write about and/or utilise narrative in the research. Geertz (1973) is an early advocate of what he called thick description, essentially, story. Connelly and Clandinin (1994; Connelly & Clandinin, 1990) propose that we all live storied lives and thus advocate narrative as representational style and research method. Wallace’s work with Louden and Mulholland (Louden & Wallace, 2001; Mulholland & Wallace, 2003; Wallace & Louden, 2002) builds upon Connelly and Clandinin and considers science educators. Wallace is careful always to include issues of ethics and rigour, important due to the relational nature of the research process—“The relationship between participants, researchers and audience...determines the nature and degree of collaboration and consultation around the formation of various texts” (Wallace & Louden, 2000, p. 155). As noted elsewhere, I was very much aware of ethical considerations and took caution to ensure collaborative meanings were established, reviewed and reinforced throughout the study. Brickhouse’s (1992) ethic of care actually drove my choice of the phenomenon of CARE AND CONCERN and is a source I do not diminish.

In keeping with literary qualities espoused by Richardson, I avidly read several Australian authors, notably Carey (Carey, 1985, 1991, 2000, 2001, 2006, 2008) and Humphries, the former for his characteristic voice, obsessive description and vivid prose, the latter for his ability to chronicle autobiographical events with a high degree of vraisemblance, encompassing mirth and keen observations of human-kind (Eisner, 1997; Ellis & Bochner, 2000).
Theory, method & methodology

Theory provides the roots, Method the means, Methodology the frame

For the purposes of the literature review, I present the theory, method and methodology last. The fundamental texts I drew from extensively throughout the thesis have no moment, they are everpresent, the firmament which envelopes the knowledge claims I make. This does not mean that I approached theory and method haphazardly.

Theoretical framework and representation

One of the first monographs I read during the participant observation stage of my fieldwork was Wolcott’s (1999) *Ethnography, a way of seeing*, drawn to my attention by John Wallace. Wolcott guided me as I attempted to make the engineers ‘the other’ and yet observe them from internally, as an insider. A significantly lengthy period of emersion in the field allowed questions to emerge from the data. John also suggested to me that my group really was a community of practice, hence my attention was drawn to Wenger’s (1998) *Communities of practice* focusing on the single case of claims processors and Lave and Wenger’s earlier work—*Situated learning* (Lave & Wenger, 1991) proved invaluable. A detailed discussion of the applications of Lave and Wenger’s concepts of Communities of Practice, Legitimate Peripheral Participation and applications to this thesis is found section V Findings.

When I was situated in the field as a participant observer and the Supervisor of the laboratory was largely absent from the community, a constructivist learning framework (Aikenhead, 2000; Confrey, 1990; Taylor & Willison, 2002) held initial appeal for me. This is not surprising. I found vraisemblance in the notion that students were negotiating individual meanings in their search to make sense of the signal processing world. When I saw them working together, as I did Dock and Safwan, to solve a problem merely to satisfy to themselves they can solve it, I embraced the social dimension where ‘learners compare their personal meanings with those of others to develop a consensus within a group’ (Wildy & Wallace, 1995).

Later, I had the opportunity to interview and analyse the Supervisor’s interactions with the students and his other behaviour, I relinquished earlier constructivist notions. Upon considering the ultimate intent of the Supervisor, I returned to the apprenticeship model of becoming and being an engineer. This is when I considered constructionism (Gergen & Gergen, 2000) and later approached post-structuralism. Schuerich’s (1997) nodes as detailed in *Research in the post-modern* provided an important three-dimensionality, i.e. projection of ideas back into history and out into the future, which I find lacking in more simple apprenticeship models, see also theoretical framework. In considering the role of the Supervisor as a contextualised figure within the history and tradition of his upbringing, discipline and promise for the future, I found Bordieu (1977) and Chrisians (2000) important referents.

Method support

I considered a number of methods to analyse over 500 pages of interviews and observational data. The techniques I considered ranged from Nvivo, to discourse analysis (Silverman, 1993), to analytic induction (Mulholland & Wallace, 2003). I attempted to adopt the de-centered researcher position suggested by Scherich (1995), particularly with respect
to interviewing, but also utilised some techniques from Carol Steiner’s *Magic Moments*: Lengthy emersion in the field, initial constructivist framework, Questions arise from data, Repeated access to members in cohort. Steiner allows the reader glimpses into the lives of the professionals she shadowed, and admits when her data arises from ‘informal conversation’. Informal conversation is the sort of data we collect in any human interaction. Informal conversation contains information, miss-information, indelible and fleeting impressions. Conversation as research method has some challenges. How do we record it? How do we value it if it contains misinformation? If we did not glean some value from informal conversation, we would not continue to discuss, conference, negotiate, etc. Informal conversation relies on core vrassemblage, but with a filter—the filter of what we happen to remember, the filter that any conversation contains unconscious lies and half-truths and conscious dis-information. In dealing with the dialectical tension between essay and narrative or conversation, Jackson (1998) declares that

To reclaim narrative is thus to retrace history to a time when direct experience constituted a form of truth, when wisdom and knowledge had not parted company, and stories were the commonest way of communicating and sharing the trials of life. And yet, as Foucault reminds us, the essay once possessed this very function—as an essay or experiment in which the author’s identity was tried, tested, and put at risk. Foucault celebrates this mode of essayist writing as a form of ordeal [épreuve] that transfigures self in the pay of truth. Instead of an appropriation, arrogation, or conquest that simplifies in order to communicate, it assumes the form of an askesis—“an exercise of oneself in the activity of thought” (Foucault 1990, 9). Adorno also celebrates the essay as an antidote to the philosophical habit of seeking only the universal and enduring, and eschewing the inconclusive, the tentative, the digressive, and the open ended. The essay, he notes, may be a bridge between science and art, at once an implicit critique of system and a testimony to the value of experience and irony in a world captivated by categorical thought. (Jackson, 1998, pp. 6-10)

I understand from Jackson that a certain legitimacy or “proof” exists from a careful askesis of both essay and narrative. Equally, I note an interest in providing ‘direct experience as a form of truth”. Hence, I present frequently to the reader the actual extended quotes or conversations from the students or supervisor. In sharing of the Supervisor, the students, and myself, I seek to provide echotypes, only to provide instances where the achetype doesn’t work perfectly or where I can find the inconclusive, tentative, and digressive. Indeed, I intend my work to be as much social science as art.

When I consider merging story with essay, I align directly with Jackson in *Minima Ethnographica*. (Jackson, 1998) I cannot know in an absolute sense the truth of the laboratory, or be assured that any other laboratory would necessarily evidence the same phenomena. I can surmise that, certainly commonalities abound, but I cannot state unequivocally. Hence, I am very careful, perhaps overly so, to present multiple points of view, multiple voices, and even multiple methods for study.

In this sense the essay merges with storytelling, which, Hannah Arendt observes, “reveals meaning without committing the error of defining it (1973, 107). The storytler testifies to life as it is lived rather than seeking to get beyond the particular situation of which he or she has direct experience in order to say something authoritative about the nature of the world. Stories bear witness to our search for some kind of provisional faith or wisdom that will make life bearable, rather than to our need for transcendence in a body of knowledge that ostensibly holds good for all people at all times. So it is that stories help us reconcile ourselves to the ways things are, rather than point to ways in which the world may be changed. (Jackson, 1998, p. 34)
Representation

Writing up this research is not like uncorking a bottle and pouring out the contents (van Maanen, 1988); rather it involves us in making sense of the three different kinds of data and weaving a narrative thread around this sense-making process. (Wallace & Chou, 2001, p. 698)

I use a metanarrative, intersubjective approach, where, like Wildy I:

...started from an empirical problem, moved backwards and forwards between my data and the literature to arrive at theoretical constructs, seeking to capture the complex, subtle, and shifting meaning that [participants] principals created of their experiences... (Wildy, 1999, p. 15)

However, I did not develop a grounded theory, with its coalescence of data into a single core category. Instead, I chose the narrative account for my representation. In this way I allow for divergence and richness in capturing the particular and the context. The title of this thesis presents a dualism, a paradox. Knowledge cannot be sacred in a positivist modern sense because knowledge is scientific, empirically derived and replaces religious and mystic references. Shils, as cited by Schön, notes that, ‘secular knowledge continued the mission of sacred knowledge...where fundamental, systematically acquired knowledge was thought in some way to be a step toward redemption’ (Schön, 1995, p. 35) (see also section V, Findings).

I am a researcher in education, but I come to the PhD after many years of working with and among postgraduate research students and general research in Australia. In 2003, I began studying a laboratory of engineering students that I knew well from my practice. In fact, I recruited two of the members of the laboratory. I dwell in the area of social science, but those with whom I act in this thesis dwell in the realm of algorithms, the hermeneutic statistical study of the detection of signals. Stereotypically the engineers have a belief that they uphold and even represent empirically derived knowledge. For the eight students (3/4 of who are international students) and I, a profound underlying current is the redemptive power of education to improve one’s status in life. So in a dualist sense, the knowledge they (we) produce and in fact the day to day happenings of the group, be they algorithmic or biorhythmic, are imbued with knowledge that is sacred, rising from sacred textualities.

The happenings and written representation are sacred because they contain some of the heretofore unwritten code, the tacit knowledge of decades of ways of training engineering PhD students traditionally. The thesis tells a story of the laboratory and the ways we lived the years between 2003 and 2006. It is sacred because it contains details which can only be known by daily and intimate contact with the group. It is sacred because some of the stories it tells may or may not reflect actual events as they happened, but may somehow be a distillation or concatenation of an event or detail, or perhaps not even true in the realist way stories are conventionally viewed. It is a sacred text because it contains and is contained within parables and commandments of the Master.

The meaning, the fundamentality of this thesis lies in sacred knowledge, a knowledge that I came to via in-depth immersion into the training of acolytes in statistical signal processing. The sacred knowledge of which I speak is not necessarily scientific, but has the potential to blur traditional researcher/researched boundaries intersubjectively. It is a knowledge shared by supervisors, students and friends as each learn and grow over a three year period. The meaning we make is through the pedestrian lives we lived through each other. As Jackson notes:
This is because the authority of the scientific essay stems not from a communis sententia arrived at through shared experiences of mundane life but from an exclusive knowledge that defines the precinct of a professional and privileged class (Lyotard, 1984, 25). Always arcane, always couched in cabalistic language, always the preserve an elite, essayist knowledge implicitly divides those in the know from those in the dark. (Jackson, 1998, pp. 34-35)

Knowledge which is created in the mundane existence of students in the laboratory has a basis in the fundamental and innately human trait to self-organise, to assert authority or be submissive as deemed appropriate to the construct of time, place and moment. This is the essence of an intersubjective approach. More discussion of Sacred Knowledge will be found at the end of this thesis.

**A post-realist view?**

Below I conjure a structure to my thesis which consists of a **tone, representation and sufficiency, my decentred position, some definitions** (archaeology, node, formation, webs of significance and influence) followed by an outline of the thesis chapters.

**Tone** By way of introduction, I have drawn upon the work of James Scheurich and his book *Research method in the postmodern* (1997). Where Scheurich’s notions of post realistic representation and theoretical framework aren’t as well articulated, I call upon a work released one year later by Etienne Wenger (1998) *Communities of Practice*. It is useful to note that Scheurich’s ideas are based upon his research in marginalised ethnic groups in the United States, particularly North American Indians, African Americans and Hispanics—therefore classifying him if I need to do so as critical race theorist. As most of the students in the laboratory are from the non-dominant (including me—a female amongst all male engineers), non-Western cultures, Scheurich appropriately sets the tone for my thesis.

**Representation and sufficiency** For over a year I struggled with my supervisor’s increasingly insistent plea “...so how are you going to represent all of this?” I was not sure. I practiced my authorial voice by writing autoethnography. I pressed representational boundaries by interrogating Denzin and Lincoln’s concept of bricolage, pondering a virtual research space complete with a reconceptualisation of research as intersubjectivity, and learning to be innovative as intersubjective learning (Vernon, 2007).

But none of these seem to me sufficient. Sufficient, for me, is not narrow—as in ‘just enough’ to get me a thesis. Sufficiency means that the thesis must try to be all things that I desire for my writing about my research. Sufficiency, in a sense, is my validity criterion. Sufficiency means:

- I adhere to commonly accepted academic standards in education
- I demonstrate an authorial voice which is derived from a literary tradition
- I adhere to tenants of qualitative inquiry in the 7th moment, where:

  We imagine a form of qualitative inquiry in the 21st century that is simultaneously minimal, existential, autoethnographic, vulnerable, performative, and critical. This form of inquiry erases traditional distinctions among epistemology, ethics, and aesthetics, nothing is value free. It seeks to ground the self in a sense of the sacred, to connect the ethical, respectful self dialogically to nature and the worldly environment. (Lincoln & Denzin, 2000, p. 1052)
• I present supported concepts resulting in novel approaches to issues of voice, ethic of care, realism, etc.
• I utilise a representational style and theoretical framework with vraisemblance, true to ethnic tone; yet invites readership in three arenas: Social studies of science, policy studies, namely higher degree research in Australia, and engineering

Scheurich calls for researchers to do research in their own archaeology. He notes:

What I am describing is a researcher doing research within her/his own archaeology, whereas a researcher from one archaeology researching a different archaeology raises some additional issues. When, say, an anthropologist goes to study another culture she/he is an enactment of one archaeology interacting with the enactments of another archaeology. There is, then, no discovery; there is an interaction. If the anthropologist assumes that her/his representations of the other archaeology are real or true, this is archaeological imperialism. (Scheurich, 1997, p. 180)

Through this, Scheurich gives me legitimacy as a graduate student to do research on (study) graduate students, for it is within our own web of significance that we negotiate and can make real discoveries.

**Decentred position** The position of the researcher vis-a-vis representation is of primacy to Scheurich. He argues that for research to appear valid, real, it centres the researcher as teller and interpreter. To decentre the position of the researcher within an array of culture structures, to call audio taping and pattern analysis into question, is to embark upon a path of post-realism. Scheurich notes about realism:

What I mean by taken-for granted, is that realism is a set of inter-related assumptions about researcher, research and reality that social science researchers act out of without understanding that they are doing so. …a researcher assumes that she or he is relatively independent…who has a fairly well researcher-trained ‘mind’ or consciousness that can independently…observe a classroom, see what is happening there, and write a report that gives the reader at least something of what is ‘real’ in that classroom ...to trouble or subvert representation practices without troubling or subverting subjective and research practices of reason, like coding, is insufficient, leaving, especially the heart of realism, its privileged subject, in place. …realist research typically mixes a little material reality with a lot of interpreted meaning with little attention to the nature of the mixture. (Scheurich, 1997, pp. 160-161)

In this thesis, though it is a writing, a telling by me, I originally intended to decentre my subjectivity by representing my existence in something I call ‘webs of significance’, which is akin if not directly equivalent to, Scheurich’s archaeologies. I attempt do this in genealogies, stories, codes, letters and textual representations. I shall allow all of us to speak, to speak directly from field notes and interviews. However decentred I try to make myself, I realise it is who am doing the telling, so I cannot be as decentred as hoped. So as a theoretical framework, I borrow some of Scheurich’s concepts of an archeological approach to research, but do not inscribe Scheurich into the full textuality of the thesis.

**Archeology** An archaeology is the construction of a particular complex culture dynamically interlinked and viewing a culture in this way is an archaeological perspective.

**Node** For Scheurich, the individual is a category or node within an array:
A mind or consciousness could be seen not as an atomistic singularity but as interwoven within a broader social or cultural or contextual field that includes others. In such a case an ‘I’ would be more fuzzy and diffused, less coterminous with the body, more intermeshed within its context, more interdependent. We would talk about selves, actions, and even, thoughts as less exclusively individual and more inclusively relation, webbed, arrayed, archeological. We would not think so much of an individual person thinking alone but of a context or a field thinking or, more broadly of a culture or an archaeology thinking. (Scheurich, 1997, p. 165)

Scheurich presents an interesting metaphor of individuality above; archaeology, which by any other name seems to mean culture, and formations. Formation Formations are the intersection and interaction of a dominant archaeology with another archaeology which creates ‘interactional hybridic spaces’. Scheurich suggests formations are groups with ‘relatively coherent ways of life or cultures that continue to survive within a larger archaeology’. As example, Scheurich suggest African-Americans as a formation, a group dynamically maintaining ‘their religion, their music, their beliefs, their use of language’. (Scheurich, 1997, p. 165)

I am left to infer that formations (as above) loom in contrast to other ethnic groups (Jews, Irish, Polish, Italian, British, and Dutch) which presumably have already been consumed by the dominant anglo archaeology, at least in the United States. But it is not this presumption that leaves me with greatest unrest, as I will make use of formations and archaeologies (as webs of significance) in this thesis. What disturbs me is Scheurich’s lack of defining any other colour in the archaeological tapestry—it is node, formation or archaeology. However, let me leave this for a moment and discuss the concept of archaeology in the context of this thesis. Scheurich defines archaeology as:

...we could think of a three-dimensional tinker toy construction in which the nodes are categories and the interconnections are meaning linkages connecting the categories. Some categories are nearer the bottom of this tinker toy construction because they are more important, more primary, more foundational to a particular culture...but this construction is alive, is dynamic...each culture lives as its array of categories, though over time these change and rearrange. To be a member of that culture is to live – think act, talk, be – literally in the terms of its interlinked categories or nodes. I call this whole construction an archaeology. (Scheurich, 1997, p. 163)

For me, I cannot, no matter how many times I read and re-read Scheurich and Foucault, subsume any anthropological upbringing by utilising the term archaeology for something I would (should) consider to be a culture or subculture. Lincoln and Denzin challenge:

This (sacred epistemology) is interpretive scholarship that refuses to retreat to abstraction and high theory. It is a way of being in the world that avoids jargon and incomprehensible discourse. It celebrates the local, the sacred, the act of constructing meaning. (Lincoln & Denzin, 2000, p. 1052)

Scheurich’s concepts, contextualised in the seventh moment of which Lincoln speaks, make good sense but the naming, the archeology is a word of the past, speaking of dusty volumes, old bones and stratigraphy—a layered, two-dimensional word Scheurich must eschew. I suggest a term that similarly calls ‘forth a vast array of other categories...depending on one another...deriving meaning through interlinking with a web of other categories.’ (Scheurich, 1997, p. 163) The term I use in place of archaeology is web of significance. While the web concept is seemingly obvious, the significance arises in the conjuring, in the calling to play...the ignition-- in naming, my webs are called into significance.
Webs of significance & influence The webs of significance, for the purpose of this thesis, are research, education, signal processing, engineering and studentship, to name just a few. The formations recall a formation is an intersection of dominant and non-dominant archaeologies, are, in fact, dominant in the laboratory which I study. The formations are Islam and Buddhism. The nodes are the individuals, as Scheurich has suggested—this means me, the Supervisor, and the students. We are the termini of the linkages.

But the laboratory is not the web of significance, nor are the nodes, the individuals, the laboratory. And while the formations are a constant flux in the laboratory, they too, are not the laboratory! The laboratory is legitimate culture, but not, seemingly accounted for in Scheurich’s scheme. And this is why I turn to Wenger to provide me a legitimate space which accounts for, contextualises and gives meaning to the ‘practice’ of the PhD students in the laboratory. I will argue that the laboratory is a community of practice within the web of significance, a community which I will show possesses mutual engagement, joint enterprise, and a shared repertoire (Wenger, 1998, p. 72). Utilising Scheurich allowed me early entrée into theorising about theory and entrée into the Post-modern. As noted above, however, I return everpresent to Lave and Wenger, as it is learning in Communities of Practice and intersubjectivity which provides the most permanent and viable referents for major concepts I propose.

Methods and Methodology

Overview: Methods In this sub-section I discuss both methods and methodology. First, a number of methods were designed at the beginning of the study in order to facilitate and drive data collection from several sources. This would ensure that I would have a variety and depth of original data from which to draw conclusions as to what was really happening each day in the laboratory. As mentioned, I had worked with and knew a number of higher degree engineering students in several laboratories, thus I had a relative position of privilege. I initially undertook a period of participant observation with a small group of students. Following this, I was to undertake interviews both in industry and among the students themselves. I also undertook a broad literature review of innovation; innovation in the commercial sense in Australia and how innovation is considered in higher education. For this purpose, I also undertook a benchmarking exercise with an higher education institution in the United States. Taken together this formed the first data collection phase—a pilot study of sorts. Following the first round of data collection, I was planning to collect further data from institutions in Australia and write the story of a key innovator in digital communications. However, early in 2004, I began writing as a method of inquiry and worked with data I already had collected. During this period, I began to feel I lacked sufficient background in graduate student pedagogy and commenced research in this area. After some months, I realised my hermeneutic study of engineers in the lab was novel, and there was something of a gap in the available Australian literature.

Drawing upon significant data I had gathered in this area and to further explore the student-supervisor relationship amongst my engineers, I adopted writing as a method of inquiry. From this, I made the decision not to widen the study to other Australian institutions or to include the key innovator, though an initial interview with him had taken place in April 2004. Rather, I revised the method to re-interview the same students one year after the first round of interviews and extended the study to include two recent graduates of the laboratory. Further, I decided to interview two students who were not part of the pilot study, but who had the same supervisor outside of Australia. While initially this might seem problematic, I had entrée to them because of my involvement with the research centre. The second round of
interviews had approximately the same question set as the 2003 interviews (see appendices). The interviews, one year apart, allowed me to catch up with the students, observe their progress and test the consistency of their responses.

All data collection was complete by April 2005 with transcription of the second round of interviews completed by July. In all, there are over 325 pages (single spaced, 12 pt) of typewritten field observations and 193 pages (88,600 words) of interview transcripts, all of which I recorded and transcribed myself. In September 2005, I began analysing the data from these sources. For details of observations and interviews, see Appendix 1 – Chronology of lab observations, visits, interviews, and events.

Description of methods used

A detailed discussion of the key methods of inquiry utilised in the study is suggested: these include; participant observation, ethnography, interviews, blog survey and writing.

Participant observation The period of participant observation occurred from 6 May 2003 until 28 August 2003. During this time I spent 34 full days in the laboratory recording conversations, movement, supervisor meetings, technical presentations and all manner of laboratory life. I had lunch with the students, celebrated paper acceptances and other milestones and was a confidant of some of them. When many of the group graduated with PhD’s in 2006, I had the opportunity to be with them to share the joy. I knew approximately 20 of the 30 students the principal supervisor ushered to completion between 1996 and 2008. Thus, the sustained relationships I have with many of the engineers suggest a far richer and deeper narrative drawn from meaningful personal experience. A sample of one day of transcribed field notes can be found at Appendix 4—Observation 17 of 34, 1 July 2003.

Ethnography Should I have embarked upon a strict ethnographic study of the culture of apprentice graduate engineers, I may have undertaken to analyse in depth the many and varied actions, intentions, inactions, informal and formal organisations within the group that I recorded in the field notes from the period of observation. I may have broken their movement and speech into monads or themes and my writing may contain conclusions that draw from resultant linguistic analysis. What I adopted was an ethnographic frame of reference which sought sufficiency. The ethnographic frame was drawn from Wolcott (1999) and include the following criteria for ethnographic sufficiency: distance, data, quality and culture.

Distance The researcher shall be of appropriate distance to gather data. In some cases, the researcher must become a true member of the community. In other cases the observation deck may be further and further removed. In my case, I maintained participant observer status for my work in the laboratory and for my work at the Company, I was, am a full member. Wolcott notes:

Outsider status refers to an orientation not to a membership. Against sometimes overzealous claims of insiders remind ethnographers that “you can’t really know us unless you are one of us,” ethnographers may feel an urge to remind others (or reassure themselves) that there is no monolithic insider view, either. There are multiple insider view, multiple outsider view. Every view is a way of seeing, not the way. But most certainly there was a time when, by definition, the ethnographer was always an outsider for whom virtually everything could be regarded as “different.” (Wolcott, 1999, p. 137)
**Data** Data shall be collected a priori, with the intent of answering some question. Even if one adopts a grounded theory approach, one still has a framework of the questions to be answered and where generally the answers may be found. As Wolcott notes: “...there is no end to what can be collected and subsequently processed as data. One can go in search of data (or grains) of a familiar type, selected with a specific end product in mind, or one can gather whatever is available locally and see what can be made of it.” (Wolcott, 1999, p. 248)

**Quality** The resultant ethnographic work shall possess quality. For it to be of quality, the interpretation shall enhance understanding of the phenomena. It shall possess a graphic level of imagery and description where the reader shall experience vividly the details of the stories. Wolcott reminds:

> One can do ethnography anywhere, anytime and of virtually anything, as long as human social behaviour is involved...The important question is not whether ethnography is feasible in a practical instance, but whether and how cultural interpretation might enhance understanding of the topic or problem under investigation. (Wolcott, 1999, p. 68)

**Culture** Culture is the raison d’être for ethnography. Culture is so crucial to ethnography that without it, the reader is left with crime scene forensics: random data, lifeless bodies, open windows, spatter patterns. Culture is the meaning I make of the scene, and without my interpretation you might easily walk on by; another senseless, random act of data collection. Wolcott notes:

> ...any number of concepts can be used for holding a description/interpretive account together, but if ethnography is the desired result, then culture must be among them. And culture must be added; it does not spring forth from the data. (Wolcott, 1999, p. 250)

Distance, data, quality and culture all shall be evident in order for this thesis to be judged ethnographically sufficient. I outline these criteria early on to frame the readers thinking about what they shall be reading. In establishing ethnographic sufficiency, I was cognisant also of several questions: Am I attending to the needs of the participants? Am I adequately recording the interactions and discussions? What is the effect of my presence in the lab? What part have I (unwittingly) played in the process of conjuring the students? What can I do to help them, to repay the debt I owe them for allowing me to follow them around and ask them silly questions about what they are doing? It should be noted that in my journeys, my understanding of ethnography actually changed, and later in my development as a researcher, I came closer to the work of Michael Jackson in *Minima Ethnographica*.

**Interview.** After the period of participant observation in the laboratory, I devised an open-ended interview question set, see Appendix 2—Student Interview Questions. The question set was based upon some of the phenomena I saw in the laboratory, the research literature and benchmarking exercises I undertook. The questions acted as a guideline for topics of discussion.

All interviews were conducted in the laboratory setting of the students and were audio taped using microcassettes. All interviewees gave formal written consent to be interviewed on the condition that the interviews were strictly confidential, and that information about the interviewee would be de-identified if used. Early in the interview process, I allowed a certain amount of deviation from the core questions as I was uncertain of how the questions would really ‘test’ with the participants. The following questions were tested and deleted either prior to or during the very first few interviews:
2. Who/what inspires you? Do you have a ‘disciplinal’ hero? What is your motivation for doing what you are doing?

12. What leads to an internationally competitive PhD?

I certainly deleted the two questions by December 2003. At the suggestion of my early supervisor, Dr Doug Myers, I asked a final question: *I am very interested in the engineering design process. Please will you tell me your view of how engineering design works?* This question also didn’t trial well—there was no commonly held belief of what design was, resulting in the students seeking to clarify my definition of design. This required me to suggest a sort of product, such as a tape recorder or mobile phone being designed. A sample of the sort of response is found below:

Tanya: Please take some time to think about it, because you are a more practical person. I am interested in the engineering design process so that…please tell me how, in your view, engineering design works.

Marvan: *First of all, if someone comes and tells you, I want this to be done most important thing to do, to ask is ‘exactly what do you want’. And give that to you, write it down and then go and confirm it after sometime. Ok. These are the specifications I have been given and you double check with them. Ok. That is what you want...and then uh then you can come up with an idea, ah how to document that...probably come up with several ideas, then you choose the best one that is maybe less costly, easy to manufacture and then you go on. Many cases the customer comes and tells you something and you give him something else. I think in a design environment ??? ...that because if you make mistake it is likely he won’t come back to you again.*

Tanya: What about in say the communications area...where you don’t know what the customers want.

Marvan: *Say you are coming up with a new product?*

Tanya: [nods yes]

Marvan: *Uhm...in that case you would have to offer customer something new which he cannot find in other products so that . It is going to be the same thing you are going to offer it has to be cheaper.*

Tanya: So then...how do you design something that is cheaper? What do you do first? Use an example, like a cheaper pencil or something. Use a common example and outline the steps for me.

Marvan: *If you are designing a cheaper mobile phone I think currently the only way you can get it done cheaper is the cutting your maybe your profit margins that’s all because nowadays the components and everything are at the lowest price All the mobile phones. If it is their profit margin I think if you look at the raw cost of the product you are all going to be all equally the same. But you can have if you want to bring marketing in, it has to be form, lightweight, goodlooking. That is what people now are attempting to do.*
If I bought a company, for me, I would manufacture something that really lasts long, like for example, machine power tools. These are not like mobile phones which change every six months. In general you make a drill, but you like to make a drill which you can successfully say, I’ll give you a ten year guarantee on it. Uh and it should not be made in uh like Thailand or China or somewhere...I never buy from China. But if it is like made in Australia then you can probably say it is an Australia product and I give you a 10 year guarantee and there, at first it will be hard to get people to buy because many people they are look at the price...see $150 and they see made in Australia $500, why should I pay $500? For just a one off, but I think you can tell people to buy quality.

Tanya: OK. That is the end...so thank you very very much.

This question made a long interview even longer, and so I was reluctant to retain it, despite the fact that Dr Doug Meyers had specifically queried me about the matter of design. Also, I felt I had to offer too much prompting, so in the end I had to overly influence the response. The question was removed after just three interviews and replaced with a question about what the student was reading at their bedside table. This question gave me a sort of feel of the kind of person the student was and also completed the interview process in a fairly light-hearted way. In the second round of interviews, the question set was modified only slightly. The interview process was enlightening in many respects. On two occasions the micro cassette tape ran out and I did not notice for several minutes. This left a gap in the interviews. Once I taped an entire interview over that of a post-doctoral student. I recalled much of the details from missing interview that evening, but later decided to admit my mistake to him. Fortunately the student was not cross to be re-interviewed. Perhaps surprisingly, he answered most of the questions in the very same way he had answered them in the original interview. The sheer volume of work it is to transcribe just an hour of interview (most interviews lasted 45 minutes to 1 hour 15 minutes, depending upon divergences) is a formidable task, even for a trained transcriptionist.

As Scheurich notes (1995, p. 244), “…there is an interplay between the interviewee and the interviewer and the interview can be friendly or hostile, informative or not. Interviews don’t necessarily reflect reality and are always relative--contextualised as any other human interaction.” For example, I believe there were times where the students told me what they thought I wanted to hear. There were interviews that may have been deliberately long and an interview which I believe was purposefully short, if not in fact, hostile. Ironically the hostile post-doc spoke to me ‘off the record’ for nearly two hours after the formal taped interview on the subject of one of the questions.

**Writing** From 2004, I embarked upon writing as a method of inquiry (see Figure 2, Schematic of research process). This writing has helped focus and re-define my research and has been intrinsic to the research process in the following three ways:

- Hone writing skills and gain authorial voice
- Focus themes for analysis
- Elucidate missing data/information

The iterative process is research in action for narrative writers. However, I had a very large amount of data to analyse. Though I categorised the major themes according to the
observations and interviews, see data analysis below, several questions remained, as I shall explain.

Data analysis

In September 2005, after reading transcripts of twenty interviews from 2003 & 2004, I discerned at least seven main catch points. It is upon these catch points that the most interesting phenomena and data from the interviews clustered. These seven main catch points were:

Need to ‘do it right’
Care and Concern
Defining Engineering/Innovation
Desire to change or do something differently during the PhD
Group learning
Supervisor relationship
Autonomy/loneliness

When I consider the responses themselves, I noted the following broad areas or categories of answers from the students:

1. Areas where students held uniform ideas, i.e. where there was little difference in individual student response
2. Areas where students provided answers which were vastly different from my hypotheses
3. Areas where I thought the responses of the students were misinformed

In order to test that my view of the data was authentic, I considered setting up a blog. Because I had been out of the direct laboratory setting for nearly a year, and I knew I would not get another chance to interview the students about the themes, I decided to test them on a blog. I suspected that I would not get much response, but I hoped I would at least get them to log-in and consider the questions. I also knew I could not have a huge set of questions. I knew it was a waste of a question where the students differed little in their responses (i.e. 1. above), so I excluded that category from the weblog questions, leaving two strong theme areas to test. The following two areas were:

- Areas where students provided answers which were vastly different from my hypotheses
- Areas where I thought the responses of students misguided

And these gave rise to the following three questions for the blog. I planned to release the questions sequentially. So after 1) was answered, I would move to 2), then 3):

**Personal Relationship Satisfaction**

1. I belong to a community which supports me personally and technically. Please discuss the degree to which YOU believe this is true or false and why.
PhD Program Satisfaction

2. The Australian PhD is very narrow; I would have taken the opportunity to do other units if this was presented to me. Please discuss the degree to which YOU believe this is true or false and why.

Supervisor Satisfaction

3. The three most important qualities of a supervisor (supervisor satisfaction) are:

   a) Technical/discipline ability
   b) Provision of environment & culture for research to happen (included internal/external)
   c) Deliberately left blank

I purposefully wrote question two to verify whether students still felt the PhD programme, without any enhancements outside of the discipline, was the most appropriate. This is because in interview the Supervisor refused to address the question. The question for the blog was written so that the students might more easily agree with a negatively framed question. While I received lively discussion surrounding questions 1 & 3, I did not get a single response from question two, despite my personal notion that research students should enhance their educative experience with other units not directly related to the thesis topic. Subsequently, the theme was dropped and no further exploration on the topic ensued. By late December 2005, I received a number of responses to the blog and was able to solidify the following themes:

   Autonomy/loneliness dualism
   Care and Concern
   Group learning
   Supervisor relationships
   Getting it right
   Defining engineering

While I have not written about all of the themes in the thesis, they all provide fertile territory for further study. I specifically excluded Autonomy/loneliness and Getting it right as major topics or phenomena for discussion. During the time when I was defining themes, I had also been concerned with an organisational referent. My supervisor repeatedly asked me “How are you going to represent this, Tanya?” I had toyed with the idea of using A Story, A Story as a narrative based organisational tool for the thesis and presented a rough idea of how this might work to my supervisor late in November 2005, which he accepted.

After I had determined the themes above, I began to map them to the organisational structure utilised in A Story, A story. In other words, I used the simplicity of the literature to frame how I would a) setup the story and characters, b) move the story forward through a kind of quest, and bring the thesis to conclusion. I used my confirmed blog information, areas where the students spoke in unison, (i.e. there was little difference of opinion), and phenomena areas—i.e. care and concern, group learning, supervisor relationship to determine the final themes for discussion. It was during this stage, early in January 2006, that I found I never had thoroughly reflected on positive areas of student lab life. I suspect it was far easier for me to see things through the trauma literature and my experience of being president of
the graduate student body—a role which brought me into closer contact with the myriad of problems experienced by graduate students across the disciplines.

So, I returned again to the data to locate evidence of positive experiences. Two questions—a) What was the most rewarding experience of their program? and b) what was the most important skill they would take to their choice of employer? provided important insight. The additional themes sat naturally as concepts within the innovation category. During this refining process, I repeatedly found the need to literally sketch out or model the themes and the links between them. Pieces of paper became a notebook. After I associated the themes to each of the sections, later becoming archetype, as defined by A Story, A Story (Osebo, Mmboro and Mmoatia), I began the long work of associating the data from interviews and observations to the emergent structure. In exploring the themes again after this definition phase, I continually found the need to return to paper to visualise the themes, concepts and how the sections would interlink. I was hampered by A4 paper so found some scrap yellow A3 paper and sketched the details of each theme under each archetype. I attached the yellow sheet to transcripts of the interviews which addressed the themes.

Upon clarifying to myself that each theme was thoroughly justified and tight, I returned to the outline I showed my supervisor in November 2005 to see how the analysis themes fit with other sections of the thesis. It was then that I discovered the material designated to sit before the story was in awkward contrast to the tightly organised story section. This movement between the data and the themes, allowed me to articulate the inter-relationships much more clearly, as did a large map I created at this stage. I made this map by taping together 15 sheets of A4 paper. To this, I added the structure, sketches and text from A Story, A Story. The above appears labourious weaving between data, themes, representation; however, I cannot envision another naturalistic method which would have yielded the same resultant themes. Jackson notes:

This is why the view from afar gives us no purchase on human reality unless it is complemented by and compared with a view from within. Recognizing this interplay between the forces that bear upon us and the projects whereby we reimage and rework those forces makes any description of human reality both a matter of science and of art. (Jackson, 1998, p. 25)

The notion of being very close to the data is one that I return to continually throughout the thesis. I am careful to present much of the data as I have transcribed it from interview or from observation. And, too, while I was somewhat distant from the students in the laboratory I observed and interviewed, the same claim cannot be made about the Company. Here I was, am, a full member of the community. I am not only close to data, I am the data! “I’ll tell you about the Dreaming, My Dreaming. I don’t have a Dreaming. Not something out there. It’s in here!” He touched his fist to his chest. “I am not the dreamer, I am dreamt.” (Jackson, 1998, p. 198) When one dwells in the data, the data becomes you! Mulholland and Wallace, calling on Erickson, describe the process of analytic induction used for “Strength, Sharing and Service: restorying and the legitimation of research texts”:

Data sources were read, and events, episodes and transactions marked when they represented instance of phenomena of interest. When coding in this manner, we acted as the instruments of research...(Mulholland & Wallace, 2003, p. 10)

Like Mulholland and Wallace, to code and categorise, I drew upon the corpus of research relating to PhD studies, my previous experience in managing research and education portfolios, and importantly what it was like to be a student. Contributing to the validity of my work was the longitudinal way in which I executed the interviews. I asked the same questions
of each student, one year apart. In general, responses did not deviate from 2003 to 2004. As detailed elsewhere, there were phenomena which I excluded as they did not ultimately contribute to answering the question of “How does the graduate engineering student innovate.” To better understand my progression through the stages of my thesis, I call upon the metaphor of moments from Denzin and Lincoln.

Moments

More than any prescribed approach to the data and analysis, the process described above was a naturalistic and iterative approach to data acquisition and information processing. The following description of the four moments, as I now call them, of the thesis is a retrospective look at the process of ‘teaching oneself what one doesn’t know’. The moments describe the phases of my becoming a researcher and making meaning—a process I did not know about nor did I purposefully map from the beginning. I do not claim it is a novel approach. The moments are mapped on Figure 1 Research Matrix.

First moment The first moment centers upon innovation and technology, it is during this time that I undertook extensive literature reviews and searches in innovation, attended innovation conferences and held regular meetings with engineer/innovators. Moreover, I visited industry and met with engineers working in the field. I undertook research writing about the innovation economy in higher education in Australia and undertook a benchmarking exercise with a higher education institution in the United States. This moment occurred approximately from May 2003 until January 2004.

Second moment The second moment centres upon graduate student pedagogy, including matters relating to the position of student and supervisor. During this period I undertook extensive literature reviews and a policy and practice survey of the 39 higher education institutions in Australia. As above, I undertook research writing both from the point of view of the student and the point of view of the Supervisor. This moment occurred approximately from January 2004 until July 2005.

Third moment The third moment centres upon data analysis. This moment incorporates the final transcription of interviews, analysis of the data for themes and publication of a weblog to verify the themes. As noted in the literature review, each of the moments has its accompanying literature reviews, methods. See also Figure 1 Research Matrix.

Fourth moment The fourth moment describes the final writing up of thesis and drawing conclusions toward defining innovation. The moment was deeply affected by Michael Jackson’s (1998) Minima ethnographica and my two years immersion in the power driven world of U. S. Oil & Gas industry. This moment continued from 2007 until now.

Validity

For validity I rely on upon two distinct classes of quality criteria to drive how I wish the thesis to be judged. One is a class of Academic criteria, and for this I utilise: STRENGTH, SHARING and SERVICE from Mulholland & Wallace (2003). The other is a class of Literary criteria for which I draw heavily upon Laurel Richardson and her concept crystallisation. Both have aspects of the other but are different. The Academic criteria seek to focus the outcome of the thesis the discipline of science and mathematics education, the Literary criteria seek to ground the work firmly in the postmodern tradition. In a very real sense, the two criteria
mirror two sides to my approach to written work—one the more scientific, analytical, rational, and the other, more painterly, impressionistic, intuitive.

**Academic quality criteria**

I briefly discussed STRENGTH previously so the reader can read this section II Context with the quality criteria of STRENGTH fresh in their thoughts. However, I will now more fully discuss the criteria by which I wish this thesis to be judged. In this, I have specifically, like Mulholland & Wallace, selected sections which are particularly indicative, or relative to that criteria. Hence, the STRENGTH criteria have much to do with the fundamental way the researcher conceives of the study and executes it. In a sense, it is the skeleton or frame of the entire body of work. In the next section III Analysis I actually present five phenomena I observed in the lab. I present both field data and analysis in this section, and draw conclusions about the phenomena. At the end of this section, I propose a model of graduate engineering knowledge acquisition.

Because I spend a lot of time with the data, presenting it to the readers so they can judge for themselves, the criteria by which I wish this to be judged is the SHARING criteria. This section will have a high degree of vraisemblance or verisimilitude because it dwells closely to the data. Readers who have been part of labs or even research groups will easily understand the camaraderie and ebb and flow of student life I present in *A day in the life*. They will recall the laboratory “brain” who likes to work out all the difficult equations or quote Foucault at length, the self-actuating positive student and the morose student, the lab clown who mucks around, but makes others laugh, and they will notice how common the assembly of a journal article is, whether one is in science, education or engineering. In the III Analysis section, I am careful to use a story to illustrate each of the phenomenon. These stories use participant dialog especially selected for their ability to speak directly to reader—like a script, or as if the reader were directly a part of the interview, lurking. I later interpret the story and the meaning I ascribe to the story. All of such values I hope contribute to the SHARING Criteria. According to Mulholland and Wallace (2003, p. 8) the SHARING criteria, involves ‘qualitative work which is shared with others who, through reading, experience vicariously events and phenomena described’. They also connect the SHARING criteria to thick description and the ability of the text to show ‘that interpretations are based in context and the participants’ and not the researchers’ imagination. (ibid) While the analysis section is certainly the most dense in terms of thick description, however, I continue to use field texts to a lesser degree to the end of thesis.

In the final three sections IV Linkages, V Findings and VI Epilogue, I present a model of Graduate Engineering Knowledge Acquisition, definition of innovation in graduate engineers research and my own thoughts on intersubjectivity, innovation and the anthropological project. The criteria I wish these three sections to be judged, collectively is service. Because these sections offer the reader my original contributions to the stock of knowledge, where I suggest hypotheses about learning and innovation among graduate student, it is perhaps natural that this section be judged by the SERVICE criteria. As Mulholland and Wallace note (ibid), the SERVICE Criteria concerns itself with ‘the outcome or purpose of the study’. They continue to discuss referential adequacy is: “...when a reader is able to find in it the qualities the writer discussed and the meanings that are ascribed to these qualities. In addition, a reader needs to be able to see what he/she would have missed without the researcher’s assistance.” (ibid) I try to be careful to point out to the reader, throughout the thesis, the things they might have missed. This is especially important because I utilise extensive
amounts of field data, where I do try to highlight in the discussion and also by bolding the text which is of greatest interest or relevance.

The ultimate test of whether a writing is of SERVICE is if it possesses Naturalistic generalisation where case materials have been presented in such a way that the reader is able to make meaningful comparisons to other cases. So, for example, if the reader is able to consider my Graduate Engineering Knowledge Acquisition Model (GE-KAM) and say “Hey, we can use this model in our department, we just need to make a few tweaks to the way we do a) and b).” Alternatively, if the reader says “According to this, our supervisors aren’t allowing students enough of their own space, they are not allowing enough student self-actualisation.” Or if policy makers read the thesis and say “Wow! We should consider some of these capacities rather than ones we have been working on for so long...”. In other words, if the reader is able to mentally map some aspects of my GE-KAM model, definition of innovation or intersubjective journeyings to more general cases—then this thesis can be judged to have been of SERVICE to the discipline.

**Literary quality criteria**

I have several additional literary quality criteria by which I hope my thesis to be judged. Mulholland and Wallace do not address literary quality in Strength, Sharing and Service, however I add these because in learning to flex my authorial voice, I have come to embrace a more literary point of view. Perhaps the greatest driver of my creative literary self (as opposed to my scientific analytical self) was taking a constructivism unit with Professor Peter Taylor at Curtin University in 2003. In that unit, and in working with one of his students, we explored and shared with our fellow students Writing Narrative as Research Method. Since that time, I write creatively, usually as a break from research writing. I embrace Laurel Richardson, whose preserved voice in the *Handbook of Qualitative Research* has guided me these many years. She says:

> Writing-stories sensitize us to the potential consequences of all our writing by bringing home—inside our homes and workplaces—the ethics of representation. Writing-stories are not about people and cultures “out there”—ethnographic subjects (or objects) — they are about ourselves, our work space, disciplines, friends, and families. (Richardson, 2000, p. 932)

In writing this thesis, I write the stories of my friends, myself: my family; they are not my ethnographic subjects; they are of me. So the way I want to write about them, because I care for them and portrayals of them, is that I want to represent them fairly and ethically. But I would prefer it if I had the freedom to use elements of poetry: “...rhythms, silences, spaces, breath points, alliterations, meter, cadence, assonance, rhyme and off rhyme.” (Richardson, 2000, p. 933) I am reminded that it is Richardson who advises about postmodern texts—where data is not triangulated in a quantitative way, but is crystallised:

> I propose that the central imaginary for “validity” for postmodernist texts is not the triangle—a rigid, fixed, two-dimensional object. Rather, the central imaginary is the crystal, which combines symmetry and substance with an infinite variety of shapes, substances, transmutations, multi-dimensionalities, and angles of approach. ...What we see depends upon our angle of repose. In postmodern mixed-genre texts, we have moved from plane geometry to light theory, where light can be both waves and particles. [Emphasis added](Richardson, 2000, p. 934)

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3 For researcher poem, written at OISE, University of Toronto, Toronto, Canada on 17 July 2009, see Appendix 7.
The concept of the angle of repose has been my driving force since reading Richardson for the first time in 2003. What it meant for me then, and now, is that there is never one truth. There is a continual coming to knowing, but the angles change, and the crystals change also. My coming to knowing is different each day that I come to know me. And media has changed since Richardson, also. As I wrote a friend recently after a long e-mail thread on our BlackBerry’s: “The e-mails we exchange do change the exchangers.” This may be especially true with e-mail because it is formal, written, but immediate...how virtually wonderful, how quickly the crystals can align and re-align if a written dialog, a full written dialog can be the speed of light? (See Appendix 3—Risotto—an existential discussion on my Blackberry)

What crystallisation means for me in terms of Literary quality criteria is that it provides enhanced validity, a validity arrived at via deeply evocative texts where I have embedded, as my operating system, a literary quality which takes into account the following:

- Use of mixed genres and polyvocality (crystallisation)
- Keen observation and descriptive devices
- Transcription of my own data
- Attending to point of view, metaphor, pace, tone, and time.

**Literary Sufficiency**

**Mixed Genres and Polyvocality** Richardson has suggested that employing mixed genres, where: “...the scholar draws freely in his or her productions from literary, artistic, and scientific genres, often breaking the boundaries of each of those as well”. (2000, p. 934) I have tried in this thesis not only to embrace multiple methods; participant observation, ethnography, interview, but also interweaving mixed genres. In this, I use archetypal fiction in A Story, A Story, I use e-mail information, blog data, and a BlackBerry e-mail exchange, I even use humour. I pay attention to voice: is Dock speaking? I the Supervisor speaking? Am I speaking to you, the reader? All voices, even those who speak negatively, have equal privilege in the thesis. If there is anyone who speaks loudest, indeed it is the students whose many words and deeds are recorded and replayed for the reader, here.

**Keen Observation and Descriptive Devices** Any fiction writer will say the key to story is recording and retelling appropriate and relevant detail. Detail can only come from keen observation. In this matter, my skills as observer were honed and I became quite skilled in recording what was literally going on behind me. I logged over 100,000 words over 34 observation periods. I transcribed each of these sets of field notes to text. At the end of the three month observation period, I was so familiar with their behavior that I could predict what might happen the next day. Longer time in the field was then no longer required. My rendition of Story 1 – *A Day in the Life* of the laboratory is a synthesis of several days into one.

**Point of View (PoV)** Point of View is crucial to Richardson, who says, to re-iterate: “What we see depends upon our angle of repose.” For Point of View, and from the outset of the study, I wanted to dwell deeply in PoV. Hence, I observed, questioned, re-questioned, and continue to re-question until today. Only in this way, in continually sifting through the data from all data sources - student, supervisor, me, industry - am I able to make strong statements from multi-PoV. A prime example is the concept of innovation. I have presented to the reader a definition of innovation from the point of view of the Supervisor, from the students, and from my own point of view.
Organisational metaphor/archetype In writing this thesis, I embraced some literary qualities which I desired for my thesis—namely sufficiency in vraisemblance. Hence, I chose the 1971 Caldecott medal winning book A Story, A Story not only as a referent for the chase for innovation, but also thesis writing itself. Simple parables used to illustrate more complex thoughts, emotion, or ethics and are a tradition as old as verbal communication itself. The story is replicated in its entirety at selected points in the thesis. A copy is available in the inside front cover pocket of the thesis.

Pace The cadence or pace of the thesis is extremely important to fulfill the sufficiency of the literary quality. The organisation is not evolutionary, but tightly constrained, based upon the 5-3-3-5 ‘stanza’ model, with the patterning interweaving itself not only within each section (n.b. III Analysis), but overall through the thesis. The pace was carefully mapped out so that I No Stories and IV Epilogue each have three sections—essentially framing front-ways and back-ways, and then the stanza model commences: II Context has five sections: Rationale, Literature Review, Representation, Method, & Validity. III Analysis has three sections: Osebo, Mmburo, Mmotia. IV Linkages has three sections: Student Most Rewarding Experience, Defining Us, and Most Valuable/Fundamental Skill. V Findings has five sections: “How does the Graduate Engineering Student Innovate?”, Defining Innovation, Zones of Development, Translational Dialog and Sacred Knowledge. The VI Epilog has retained the stanza schema and has three sections: Commercial Innovation and the Anthropological Project, Intersubjective Journeying and Learning Commercial Innovation Intersubjectively. This paced model can be likened to poetry or song. The structure was not happenstance, it was mapped a priori in 2006, and serves today as an internal crystallisation of structure upon which all of the data and findings rest.

Tone The reader will note that the thesis has sections which allow tone or inflection—in other words, it is not neutral thesis devoid of emotion. These sections are primarily III Analysis and V Findings. In these sections, I allow the students, the Supervisor and myself the luxury of our own emotions and feelings. From the analytical and calculating supervisor in APPRENTICE LEARNING to the resolute student, Dock, in SOLVING TO SOLVE, to the dark and light of Zahir and Brad in CARE AND CONCERN, to the playful Safwan in VOLUNTARY INATTENTION to the seeker Tanya in MANUFACTURE OF KNOWLEDGE. In this, I imbue Dock, for example with confidence, certitude, and great intellect. I allow Zahir to be morose, Brad to be chatty and amicable, Safwan to talk about the urbane but amusing “Pizza Number”, and myself to be tentative, but ever seeking another new interpretations, new ‘angles of repose’. In the section V Findings the students are able to express their hopes, dreams and fears—they speak of their most rewarding experiences, how they define engineering and what they think will be the most valuable skill. The reader understands that these are how the students feel about what they do, hence they contribute to the literary quality of tone.

Time The story I tell about the engineers in the study is not only their story, but mine as well, especially as I have continued my research and learning journey long past my first few years gathering data. The thesis makes an effort to chronicle the process of achieving a PhD, not only theirs, but mine too. As such, I say how I have gathered the stories, and how I make them accessible to others. Therefore the readers will note I have explicitly included temporal data which identifies when, where, how and why things are done. A prime example of this is the process by which I analysed my data (see Method).
Author subjectivity

One of the basic findings of my thesis espouses learning innovation Intersubjectively. Intersubjectivity is a brand of subjectivity which is deeper and more subjective than the garden variety of subjectivity: it is a dwelling in and dwelling on occurring at the same time. What this means is that I believe what has been written here is the sense that I make of a research project which I designed and executed—a play that I wrote, produced and in which I acted. As such, I am unsure if there is even a smidgen of objectivity. I have lived an intersubjective life with the students in my study, and I now live an intersubjective life in industry. Nothing can be removed from the concept of 'being in relation to'. Had one thing been different—had I had a different supervisor, if I didn’t have access to the lab of students, if I didn’t work in industry, all would be completely different now. Thus, the stories I weave together here in the thesis are modeled upon others like it in education, but even using the same methods, the same literature review, the same data sets, the thesis cannot be exactly replicated as it appears here. And, as a work of my narrative, my ‘writing-story’ it shouldn’t be! I can offer researchers in education and anthropology several models, several new terms, and possibly a new researcher methodology in the ‘intersubjective method’; but I cannot offer replicability in any sense, general or specific.
III Analysis
3. The price of my stories

Ananse bowed and answered:
“I shall gladly pay the price.”

“Twe, twe, twe,” chuckled the Sky God.
“How can a weak old man like you,
so small, so small, so small, pay my price?”

But Ananse merely climbed down
to earth to find the
things that the Sky God demanded.
How is knowledge acquisition driven in a graduate engineering laboratory?

My fundamental thesis question is how does a graduate student in engineering innovate? I unpack this question, identified at the beginning of my study, with the following two questions: How is knowledge acquisition driven in a graduate engineering laboratory? And What is the nature (or purpose) of the PhD? I have analysed my data in terms of the fundamental thesis question, and in this section, I specifically consider data which assist in answering How is knowledge acquisition driven in a graduate engineering laboratory? In order to tease from the data an answer about how?, I present six stories of phenomena I observed. For the reader to derive a sense of vraisemblance, or strength about the truth of these six stories, I contextualise them by first presenting a full day in the life of the lab. Entitled One fine day, the transcript is a minute by minute observation of a day in the life of the students. However, it is actually not one day, but a concatenation of at least five or six days of observations.

With this as background, I can more fully explore the six stories which form the basis for further analysis of “how” does a graduate student in engineering innovate. The stories shall refer to One fine day as well as to other stories. The stories presented are: The Supervisor, Dock, Zahir, Brad, Safwan and Tanya and they represent the following phenomena which come from the data: APPRENTICE LEARNING, SOLVING TO SOLVE, CARE & CONCERN, VOLUNTARY INATTENTION (play) and MANUFACTURE OF KNOWLEDGE as I have noted previously. The order of presentation is important. I do assume that adult knowledge acquisition interweaves and is formed and informed by (everyday) experience where work, social life, or home life take turns in centrality. In presenting the stories, I suggest an order or process which commences with APPRENTICE LEARNING and concludes with the MANUFACTURE OF KNOWLEDGE. It is a process which I present in a linear way, but readers may say, “Oh, but if the students didn’t have a social network they couldn’t have apprentice learning”. I present the phenomena in a deterministic way, but in reality, any of the phenomena, on a given day and with any given member of the lab, can take precedent over the other. So, while I impose a path to discover the phenomena and themes they represent, they are merely literary devices which allow the reader to better follow the process, a process, which, in reality is both random and determined.

In the section following the stories, I undertake analysis of each of the phenomenon and associated themes in order: APPRENTICE LEARNING, SOLVING TO SOLVE, CARE & CONCERN, VOLUNTARY INATTENTION (Play), and MANUFACTURE OF KNOWLEDGE. In keeping with a literary metaphor, I present the analysis in three broad sections or archetypes—Osebo representing the Supervisor, Mmboro represents the hive of students, and Mmoatia representing a muse: an external driver of knowledge acquisition such as create/innovate impetus. After section IV Linkages section, I postulate a Graduate Engineering Knowledge Acquisition Model (GE-KAM) which is iterative and forms three major ecologies in knowledge acquisition in graduate studies: Network, Social, and Knowledge.

Stories about getting knowledge In this section I focus upon one vignette and six stories: the vignette is entitled One fine day, and the stories of The Supervisor, Dock, Zahir, Brad, Safwan and Tanya. The Supervisor is represented by the archetype of Osebo, the students, embodied in the stories of Dock, Zahir, Brad and Safwan, are represented by Mmboro, and innovation is represented by Mmoatia.
For four months of field work, approximately 2 days per week, for a total of 34 days of observation, I followed a similar routine: arrive at the laboratory, organise my wirebound Foolscap A-4 field notebook, and begin making observations, eat lunch between 12-1, return to making observations and depart between 4-5. That night, or the following morning, I would type up the notes from the day’s observations. For a detailed chronology of observations see Appendix 1 – Chronology of lab observations, visits, interviews and events. I tried to be unobtrusive, to not become involved in their lives. But, at the end of the four months I knew all of the personal gossip, the status of Safwan’s car and Dock’s wife’s pregnancy, that John was selling his caravan park, and that Saif was a member of a Edwardal family. I assisted them where I could, and years later, when one of them had a back injury, I brought him into my home for a brief stay after leaving hospital. Many of the conversations I could barely understand because of the jargon (see Appendix 4—Observation 17, 1 July 2003). While my days were punctuated by lunch, theirs were punctuated by tutorials, labs and meetings with undergraduate students, supervisors and occasionally, a technical meeting. The following did not happen all on one day—this is a simplification of many days into the one, and as such, it has been smoothed with some minor changes in time notation to account for the length of events as they would normally occur. Observations from my field notes are in italics. Items in [brackets] indicate lengthy discussion in technical language which I didn’t catch or which I didn’t include herein for brevity, or which I simply didn’t understand.
One fine day
A day in the life of the laboratory

9.30 I arrive at the lab. I am late because I had just visited my supervisor in Engineering. Present: Marvan, Safwan, Yasir, Bishr. Dock, Tom and John absent.

I begin to organise my desk and Marvan offers to give me a box for the papers I have around.

Observation: I find a notice announcing a seminar on “How to pass your thesis with flying colours”. Rajan had written a small note to the students encouraging them to attend. However I find that not one of them actually went. I wonder if there was room, or if PhD students in this group feel they don’t need that ‘rudimentary stuff’. Resolve to ask that question in interview.

[Marvan leaves.]

9.55 Yasir goes over to Bishr—speaking in Indonesian. Bishr looks up to him, nodding and speaking very quietly, if at all.

9.57
Safwan: See Marvan...this is a realistic signal. See, it is res/cosign. I assume this long tail.

Marvan: But this is only partial...Let me show you...I did this in my thesis.

Safwan: I took it only from here to here [indicates a frequency or spectrum].

Marvan: Then you know how many will interfere. So why don’t you...

Safwan: To make it more general, I did these four...

Marvan: So why don’t you [explains something]

Safwan: So you [explains].

Marvan: What I am saying is that if this affects 10 then why...

Conversation continues in detail.

10.01 Yasir goes over to Bishr again and they leave. After this, I do not see them for some time.

10.03 Lab outsider enters the lab. He says “Let's cross our fingers.” (He opens door and shows someone the room). “I’ll leave it for now. That concertina wall will go back...as compensation for lost space.”

Dock arrives at 10.10.
10.35 Marvan goes to printer and returns.

I hear a noise...it is voices, but coming from a laptop. I note Dock listening to something via earbuds. Safwan is deep in thought, also listening to something, but with headphone.

10.56 Rajan comes in. He greets me personally. “Guys, if you have written any papers or attended any conferences or submitted (any papers) in the last six months, I need to know. For Taza’s presentation on Tuesday.” [Rajan is a new lecturer in the Department. He is the administrative supervisor for several of the students].

Safwan: I have some travel, and Desi is not here to pay for it for me. How do I get it paid? I know the School won’t pay.

Rajan: So what you need to send me...

Safwan: (undeterred) Now, I’ll organise my travel another way, pay myself.

Rajan: (to Safwan) Send me the information.

Safwan: So you will collect all the information about the papers, Dock?

Rajan: No, just send it to me via e-mail.

11.00 Phone rings. I pick it up. It is for Dock. Dock explains to someone else about the meaning of the memo: “I think Hamid Halv want student to do teaching tor tutorials for only six hours per week. There is a deadline—you have to submit before 7 July.”

Observation: Someone, internal to the department, but external to the lab is now seeking an interpretation of the memo. In this information seeking behaviour it is curious they call this lab...as if this lab would have already negotiated the meaning of the memo from the Head and will have an interpretation and response for it.

11.02 Phone again. This time Dock answers and it is for Tom. Dock discovers it is a student and offers to take the students details so that he can e-mail the query to Tom. He discovers it is regarding a lab report.

Safwan: Was that about a lab report?

Dock: Just a student. Do we know where Tom left his work?

John arrives at approximately 11.00.

Safwan: I don’t know, John may know... John?

John: Yeah...(John comes over)

Safwan: You, you are here...did you get my e-mail? Do you have access to the www site? [as in to post results]

John: No, I don’t have access.
12.15
It is lunch time. Marvan asks me whether I am going to be around for lunch. I tell him I am going just now to heat it up. I go to heat up my lunch. There, Dock, Marvan and I are heating or fixing our lunches. Marvan fixes a plate of Sri Lankan food for me. It is eggplant and passion fruit leaves. At the lunch table we begin to discuss culture. I ask Marvan when he came here. He replied in 1992. I asked why he came here. He replied that his sister came here in 1986 and that she wanted his brother to come here too. However, his brother chose the US, leaving the Australian application “sitting on the table”. So in 1989, Marvan filled it in and sent it off.

Then in 1992, he got a request for a medical exam to come to Australia. After that it still took time. He found out that he needed a police clearance. One day someone came knocking on the door. They wanted him to do another medical examination. He related the story of how he took the guy for a cup of tea—because you do not do business at home. Then, during the conversation Marvan gave the guy what he needed—about 600 rupee. After that, he got into Australia no problem. Marvan said that this is implicit in Sri Lankan society. Dock agreed with respect to Vietnamese society. He said particularly in the medical and public service areas. Dock reckoned it had to do with low paying jobs and the need to supplement them.

Marvan said that in Sri Lanka they have 10 people to do one job...maybe only one of them is corrupt, but that is all it takes to slow the process up. So if you need a passport, or certificate or police clearance or something, then you have to pay the money. Just as we are leaving lunch, we discover that Rajan (a newly hired academic) has just gotten his PhD awarded.

Safwan and Yasar arrive back in the lab. Apparently, they had driven all the way to Guilford to look at a Telstar “shell” for Safwan’s handicapped vehicle. It was really in quite bad condition, not worth dropping a motor into. They said it seemed they drove and drove nearly to Geraldton...!

Observation: Yasir has taken him all this way...just to look for a car engine. That is really quite amazing, and quite caring.

1.15
John arrives. I ask John whether he made the grade with his martial arts. He replies that he did, but he did not get as high as level as he had wanted. He complained that the grader (fighter) was really tough and not experienced at grading. One guy fractured a bone, and Tom sustained some injuries. We got to speaking about weight. John states that he had gained quite a lot of weight when he lived in the US—eating lots of junk because he was poor.

Rajan returns to the lab and asks if anyone has a car to go get cake to celebrate the PhD. John offers to take him, and they leave and return.

1:40 Cake is offered to all students and anyone in the laboratory. We congratulate Rajan on his achievement and discuss various social issues and the difference in the research culture at Melbourne.

2.00 Tom has a meeting with a thesis supervisor, which I observe. The following exchange is at the end of a long, technical discussion.

The Supervisor, Heng Lee Hong Leung is both a lecturer in the department and a researcher in a number of centres. He has supervisory input for the students.
Tom: The equivalency case. Now...I remember what I wanted to ask you...about this SPAWC conference. For my poster, it relates to this, but do I put in the extra bit I have learned with the detector paper?

Heng Lee Hong: Well, there is a couple of theories there...and some strategies too. There are some really clever academics and if you give them a whiff of something...they will go off and will start investigating that. But equally, you may want to get some citations from that...so then, the more you put in the poster, or paper, the better. Also, you never know what you may need for a paper...so you may want to keep that idea and paper for something you do later.

3.00 pm.
I return to my desk area and go to the coffee room to rinse my mug. John is there.

Tanya: So you were lecturing?

John: Yeah. It was for SP204—basically for mechatronics students. They took some LS stuff & put it with SP—but it was a bit of a problem because, well their maths is abysmal...really. Some of them, probably ¼ had no clue about programming or that sort of thing. ¼ have some programming as they have taken software engineering.

Tanya: Wow! That must have been hard. Did you do the tute?

John: Don Qui Lim did the lecture. I was supposed to do the lab. But the tutes, well they weren’t going well. The students said to me they couldn’t understand the tutor. So I have been doing the tutes as well. I have been upgrading their skills. Also, they had me doing a MATLAB lecture. That was pretty challenging, too.

Tanya: Yeah, I had someone very wise tell me that you never learn as much as when you teach. But to me it would be frightening when you are at the markerboard and don’t know the answer to something.

John: Yeah, I admit that is a really scary thing. But you just you admit you don’t know and tell them you have to let them know later. Then I go to Safwan and ask him. Or, you figure it out with the students.

Tanya: So you had to take what you know they needed to know, and, in light of their backgrounds, make something they could understand...you had to transfer the knowledge in a way they could comprehend it best.

John: Yeah. I love that. It just gels everything for you, because, well, you know the theory but through teaching, students often fill in the bits for you and it comes alive. It is really good. [he is really animated when he speaks about this].

John and I walk back to the lab, and I sit down. Marvan has a small electronics lab down the hall from student lab. Safwan returns from somewhere and reports “Hey, I think I something...burning, maybe rubber from the lab...”
3.45 pm  Marvan jumps up—“Shit” he shouts as he deftly negotiates the partition maze of the office, throws open the lab door and runs pell mell down the hall. No-one follows him, except, slowly Safwan.

The two of them return after 5 minutes.

Marvan: If you do that to me again Safwan, I will get you back, but you won’t know when. I will call your girlfriend, or better yet, I will do something to your car.

Safwan: Marvan, no girlfriends. You know that. Only my car!

3.55  John complains that he cannot run the test the way he wanted to. We begin to discuss simulations, the use of server time, and whether it affects other users. John reported that it does sometimes. I asked him if you let other users know you are running something big on Pandora. He said not normally because you can’t predict how the sever will use the resources when you run the simulation. He reported that sometimes it slows other users down, but you don’t know. Sometimes, they can run a few days, but when Erik (a Swedish Masters student) was here, he had a simulation that ran 2 weeks.

Tanya: “Two weeks?!” Everyone in the lab agreed that it did indeed run two weeks.

Safwan makes a call on the office phone. He says he knows he needs a Visa. He then calls DIMIA and asks a few more questions. They confirm that his passport expires in December. He explains to them the Curtin connection and he queries why he was given a two year visa only.

4.00  Tom announces he is going to his tutorial.

4.10  Safwan collects his things and says he is going to DIMIA.

Tanya: You are going to Northbridge…I mean Perth?

Yasir: That is stupid because they will probably be closed.

Dock: It won’t be able to be solved just by going there...

Safwan: ok. [puts his book down] Guys…it is always me…just do your work…I am disturbing every day. Sorry…sorry.

4.11  Safwan comes over to my desk to show me his letter from Curtin…offering him the place.

Safwan: See?

Tanya: Yeah, but it depends on what it says on your passport. Do you have it?

Safwan: No, it is at home. Maybe I should ring the Egyptian Embassy. They are very helpful.

4.20  I pack up my things and leave. I say goodbye to Safwan and Marvan and then Yasir and Bishr, and finally John.

END
The laboratory of students was a living space, a domicile. It was a space they felt comfortable enough to discuss equations or cover each other as when Dock was taking a message for Tom and planning to send it to him. It was a space to act silly, or deal with immigration. It was a space to ask pragmatic questions of supervisors about poster prep or enjoy cake to celebrate an achievement. In the above simplification of hundreds of hours of observation, I have shown how undergraduate students, supervisors, lab managers, etc, all filter through the space of the lab’s ebb and flow, One fine day.
3.1 Osebo

Ananse ran along the jungle path—
yiridi, yiridi, yiridi—till he came
to Osebo the leopard-of-the-terrible-teeth.

“Oho, Ananse,” said the leopard,
“you are just in time to be my lunch.”

Ananse replied: “As for that, what will
happen will happen. But first let us play
the binding binding game.”

The leopard, who was fond of games,
asked: “How is it played?”

“With vine creepers,” explained Ananse.
“I will bind you by your foot and foot.
Then I will untie you and you can tie me up.”

“Very well,” growled the leopard,
who planned to eat Ananse
as soon as it was his turn to bind him.

So Ananse tied the leopard
by his foot
by his foot
by his foot, with the vine creeper.
Then he said: “Now, Osebo,
you are ready to meet the Sky God.”
and he hung the tied leopard
in a tree in the jungle.

Osebo Introduction

This section is primarily focused on the Supervisor of the students. As background, the Supervisor in a laboratory of students can be considered the centrepoint of the galaxy of students and laboratory life. It is his research topics which provide the research focus for those working in the lab. Generally, the Supervisor has long established ties with industry and has several research areas which he is exploring. The exploration is generally funded by grants from the academy or industry. The grants tend to fund equipment and facilities required to undertake research. Without research support, attracting students is difficult, but can be accomplished on the basis of reputation for quality academics or quality graduands. The Supervisor in this study had graduated a number of students. He was, however, a newer researcher to the University, having arrived from Sydney several years prior. His students were a part of a Cooperative Research Centre, and members of the Department of Electrical Engineering at Curtin. Most of his students did have some sort of financial support, either in
the way of funding from grants, scholarships or stipends from research organisations in their home countries. Most of them also lectured, gave tutes or labs in the Department. In this section, 3.1 Osebo, I discuss the Supervisor as master of the lab. He is the archetypal powerful, clever, leopard who very nearly outsmarts Ananse, the spider man. His contribution, his centrality in the laboratory cannot be diminished. One of the key functions in terms of the process of academic life, of student-being and supervisor-being is the production of papers. This shall be discussed throughout the thesis, but I offer some detail in the beginning so the reader has an idea of the nature and importance of writing in the discipline. Notice in the discussion below that the concept of writing the paper to the code is so ingrained that it was first hard for me to convey to the Supervisor what I meant by my queries. It actually takes three clarifications from me before the Supervisor understands the question is as basic as it actually is. Two other themes are also considered: supervisor recognition of contributions of the student, and student independence.

Who we are in any legitimate sense is as much about how we see ourselves as it is about how others see us. That is why, in creating a montage of Osebo, I include multiple viewings, as it were—how the Supervisor sees himself, and how the students view him. In this way, I suggest to the reader that they will come away with a high degree of vraisemblance or SHARING, aligning with the view of the student or the view of the Supervisor. It is through this multi-layered vision that demonstrates the rigour of the study and the outcomes derived.
Story 1 The Supervisor’s Story

“People are tools, you have to remember that, Tanya”, my colleague told me. “Each tool has a separate purpose, but your challenge is to use them to your benefit.” I don’t think I will forget that.

Years before, when I interviewed the Supervisor of the students from whom I had collected my data and spent months observing, I wondered about the ability of supervisors to recognise and indeed, verbalise, the significant contribution I saw the students making in terms of the research and teaching efforts. So I asked a straightforward question: Are there other things that students help you provide, or help you?

The Supervisor: Of course the students help me with teaching they help me. That is what you mean, right? How they support me as a professional academic? They help me with teaching, of course, either it is in their portfolio or it’s voluntary, but one usually. The way it worked with DEG, is I asked them to get involved in teaching. But that is not the benefit to me only, it primarily is a benefit to them, because a complete PhD requires teaching as well as research, especially in our field, how to communicate, especially engineers have difficulties communicating what they do to others and that is the great opportunity for them when they teach, to communicate to others, you know, what they know and uh that is one thing, the teaching and sometimes of course you know to, they help me attract undergraduate students to do a PhD research/PhD graduate students by just talking to them by being here, so that there is continual flow of students into the group and uh and they help me do the PR of the group as well. Of course there are other things that are an integral part of a PhD like reviewing papers, you know reviewing grants, helping me write grants, doing simulations, and for me either paid or unpaid. If it is unpaid it would be like a joint project to publish a joint paper, depends. There are things they help me with, for sure.

Clearly, the Supervisor does realise the benefit to him, especially with teaching. But, he reports ‘it primarily is a benefit to them’ in two important facets: understanding the topic and communicating it. Do these, however, help the student in learning (read modeling) academic behavior? He suggests it is voluntary with the group in Australia, but in Great Britain, as I will note in the story of Zahir, it is not voluntary, but in fact is a condition of employment. The Supervisor goes on to say that they attract new students to the group, and, almost as an afterthought he seems to remember that they do a few other things like grant writing, simulations, writing, publishing, reviewing, etc, etc. The writing up of the work into journal and conference papers is serious business. Certainly, as I will point out in the story of Brad, writing is one of the most challenging aspects of being a student. When I casually mention it to the students, they seem to down play how it is actually done. On more than one occasion when I asked them to talk about how they write papers I found myself clarifying that I do really mean how? and not why? Such was the case with the Supervisor:

Tanya: Ok. Uhm in terms of writing papers, can you model the process that you expect your students to undertake when they write?
Supervisor: I can.
Tanya: Would you mind doing that?

Supervisor: I don’t mind. Usually there are, ok, so everyone who is in the group knows that there are conferences where we have to be present ok. We have to...it is the nature of the discipline... So the students know always when the deadline for submission of papers is, cause they know we need to present at a number of conferences and...and usually the mid-field, ok, and it is a critical issue uh when to decide for a beginner to start with a paper. And it depends on the quality of the students, usually. So the process is ok, these are the conferences we are always present, you A, B, C you need to, you have no choice, you have to prepare a paper. Sorry, bluntly said, that is how I do it. Those people I give the option, but the mid-field I just decide, you know they have to because they need to build up their track record and so the process starts from designating people who have to write the papers, ok and then we discuss the topic, we discuss the issue, that should be reported, written in the paper and usually I don’t want to see the papers until the draft. If the full paper is accepted... then it is decided based on funding who should attend the conference. Usually I give priority to the mid-field always to attend the conference because in the mid-field this is the time where they should know others and they should learn how to present in an international forum and come back and start writing journal papers. Don’t start too early with journal papers, so in the third path of students you should write journal papers and avoid, or given the option of conference papers. They should write, they have to write journal papers. I have a rule of two journal papers per PhD, but it doesn’t always work. But the worst case scenario I have ever had is one journal paper per PhD. And it was the Archives of Engineering; it has to be the Archives, that is the number one journal.

I found this a revealing passage about the Supervisors’ theory of how to ensure the group submits papers for the major conferences and later in the key journals (Archives is a pseudonym), and that focus was given to mid-fielders. Also, we note that the students had a minimum number of papers the supervisor requires of them, and where he requires they publish! I realise the Supervisor didn’t answer my question, so I try to rephrase it:

Tanya: So do you have a prescribed way that you suggest that they go about writing papers?

Supervisor: No, I don’t have a prescribed way uh, usually in our area in signal processing, people write in a similar way. You know, you define a problem, and have your data model and what has been done and what are the limitations ok and then you present your paper. Ok, and usually after the very first paper the students know how to write papers. The first paper is a disaster, I have to write all over it, you know and I fix it here and there because the structure is missing. It is like the first talk of a student, the structure is not there...simply not there so I fix that, and then by the second time it arrives, uh well or better than the previous time. But usually the structure is well known in signal processing, but the very first time. Your question is whether I have my own way, no—because it is the community way of writing papers, ok, unlike in social sciences or other areas. But the beginners need to be told that way, how it works, they need to be coached the very first time.

“Oh dear”, I thought, “there must be something terribly wrong with my interview style”. Again, what an interesting response, and I am getting closer because he says “no—because it is the community way of writing papers.” So! What that meant to me is that writing papers was code—hardwired into the way they did things. Whew. Ok, I tried again, since I knew I was getting much much closer now...
Tanya: So could you make that really clear for me how that paper, how papers are laid out?

Supervisor: Yeah, I mean this is the rule that I always tell students... even today in the technical meeting, what is the problem, you answer the question. You write four questions to yourself and this is a logical structure, if you write a thesis or a journal paper or a conference or a presentation. You ask yourself the following questions—what is the problem? Now leave out the abstract and conclusion. Start with the introduction. What is the problem? Then once you have answered that, in a column or two columns or ½ column... why is the problem important? That is the second question you need to answer [taps the table]... by giving some applications, by uh looking forward, vision, because you know, we will need that in 10 years or 20 years or whatever. The third question is what has been done so far to solve this problem that we have defined in the very first question. ... Ok, so one needs to be aware of what has been done in that field in that area to solve the problem. Ok so that is the third question. And the last question, which takes the larger part of the paper... what do I suggest, what do I suggest in my work? And then the facultative or the optional question would be how can one implement it and how can it be realised in a real system and so and so forth. Of course what I have done includes the comparation of what has been done already, so that is the bulk of the paper, what do I suggest, and how does it compare.

So you keep repeating this to students and but they fail to do it in presentations and papers and I need to fix that. Today was an example, it was just disaster the talk, it didn’t have any structure. And it is so easy to write those write those questions down and just focus on the questions and it just go through. It is nothing magic, it is just logical, very logical to do it that way... that is how we do it. In social sciences it is probably a little, little different, but ...

The above gives a fairly detailed story of what the Supervisor expects from his students in terms of creating the output of the lab; how to achieve it via production of papers and in conference presentation. Everything, journal paper, conference paper or talk, shall be conceived of those four simple questions: What is the Problem? Why is the problem important? What has been done so far to solve this problem? What do I propose? Because I sense the Supervisor feels that some of the students don’t always work at the expected level, I wanted to see if he was aware of, or be willing to divulge if any of his students had any issues with his supervisory style. So I ask the question: what is the most disappointing thing in your work? It should be noted that I asked everyone this question—from the students (in both 2003 & 2004) to the post-docs, to the Supervisor himself. No-one was immune from this question. I also asked it at approximately the same time in question set (see Appendices 1 and 4), after there were several, easily answered ‘warm-up’, not too threatening types of questions. Of course, the Supervisor might have given any number of disappointments, but chose the following way to respond:

Supervisor: There was a student whom I helped uh more than probably any other student, because he was a bright student, but not independent, he was not an independent student, and I helped him, quite a lot. I spent much more time than with others. And at the end, he was disappointed with my supervision. He told me bluntly, he expected me to work with him all the time as a team and he didn’t feel that I spent enough time with him. That was something that was hurtful.

This prompted me to consider how he was supervised, so I asked a question relating to that. Describe for me how you were supervised? The response is an unambiguous one:
Supervisor: Ok. But it was important for me not to depend too much on my supervisor so I can say you know it is my work, my real work, you know the ideas came from me, he learned from me more than I learned from him. ... So a student needs this recognition, to be able to say my supervisor didn’t help me that much. [Even though I was supervised very differently...] I learned a lot from him, ok. That foundation to get started, I learned a lot from his advice and so on, but the work is mine! And he always said it when I was a student—‘it is your work...it is your work’. So the mentality here is a little different, so because you asked me, you know, but they, they are different. And I told you the disappointing experience I had; they expect you almost to do the PhD for them. To feed them with ideas until they are in year four, not all of them, the best ones, the independent ones they don’t expect you, they don’t expect anything from you...they do their own thing. Sometimes you have, unfortunately you don’t have, you know those ones who come once every five years or so, you don’t have them all the time. It is very hard.

The above seems to be a critical incident for the Supervisor—that even though he put in an extensive amount of time, the student retained an overall impression as a negative experience. But, as time wore on, he also had greater duties as a more senior member of staff. Both factors lead us to believe that the Supervisor now has a preference for independent learners and thinkers. One can see how the apprentice model, where new students are given articles to read, and make sense of, as we see in the story of Brad, are essentially looked after by more senior peers. The mid-field is likely where the supervisor spends most of his time, helping them take the first tentative steps to writing for conferences.

Phenomenon 1 APPRENTICE LEARNING, Introduction

In this section, I compose a montage of the Supervisor to assist the reader in understanding how the Supervisor gatekeeps knowledge acquisition in the laboratory. He sets the tone and the mode by which students come to attain knowledge, and are connected to the academy of researchers. He is the Master in the apprentice learning equation, and while he trusts students to be independent learners and thinkers, he must be an expert in the field. In this section, I explore differing notions of hands on vs hands off type of supervision. In the next section, I will then explore how students variously handle the Supervisory style.

In A Story, A Story, Haley retells the African tale of Ananse, the spider-man. In order to obtain the story from Sky God, Ananse must ensnare three creatures found in the African savannah. The archetype I choose for the Supervisor is the leopard, Osebo, in Ananse’s story. I chose the leopard for many reasons. Like other successful researchers in Australia, the Supervisor is the leader of a group who is relatively autonomous both within the University structure and academia. The Supervisor collaborates with others in industry and sometimes academia, but primarily has spent his career carving a niche for his research area. It is within this niche that his graduate students sharpen their own research acumen before entering academia or industry. The Supervisor is a powerful but solitary focal point for research impetus. He controls student access to learning and therefore the quality of educational experience of the graduate student. He also controls factors which may impinge upon the daily life of the student. Students look to him to facilitate, protect, induct, and impart knowledge. He is Osebo: protective, solitary and controlling. As we have seen, the story of the Supervisor is rendered in a deeply descriptive way—this is due to the multiple points of view his supervisor-ship. In the following, I present the Supervisor’s self view, and the view of the students, demonstrating how, through dialectical tension of opposing viewpoints, a full montage of the Supervisor is created.
Firstly, let me consider his self view. Here I demonstrate how the Supervisor describes himself, how he looks to students for assistance in research, teaching and technical/administrative tasks such as teaching organisation, grant writing, completing simulations, and so on. In the self view, I seek, via interview, glimpses of personal awareness. In the dialogs, the reader should look for traces of autonomy vs dependence. Note that the Supervisor has established a hierarchy for the students. This hierarchy is based on requirements—of time and resources: 1) beginners 2) mid-field and 3) finalists as noted in the Story.

Self view The following gives information about how the Supervisor sees himself in reference to the students. To determine this, I asked a number of questions. The first question focuses specifically on supervisory style.

Tanya: So how much time would you allocate to the beginners, the mid-fielders, and the finishers per week?

Supervisor: Per week, that is if I am present, if I am here, right? Usually I do it, ok I have regular meetings, group meetings, technical meetings fortnightly. On a fortnight, every fortnight, so I ask some students in particular the mid-field students, to present their work and then we have a brainstorming session, that is a meeting with all students, so I give supervision through those meetings because it is a brainstorming session so I can feedback to those presenters, but they all present anyway in turn. Now, outside this, ideally, ideally there are not too many jobs in parallel I spend about in average, two hours per fortnight with the mid-field, ok, and one hour per fortnight with the finalists except during the time of completion of the thesis, writing and feedback, that is more intensive—more feedback more discussion, and with the beginners, really little time—probably 1 hour per fortnight because they have to read to absorb, and only when they have questions they come and clarify them. So I give them more of a guidance, a procedural guidance and research methodology approach, so how should they approach the problems, I mean the research degree...rather than going into the technical, because they are not there yet, unless they have questions, and they ask me what is this, what does this mean, and this and that. Because they are coached by the finalists. That is the way it works in a group. It has always worked well. But sometimes, you don’t, the time is not there and it doesn’t run the way I described it.

There are two important items to note in the above text. First, that the Supervisor focuses on something he calls the research methodology approach. This means how students approach problems in a systematic and linear way. This is something he sees as a basic deliverable to the student. Also note his expectation that new students are coached by the finalists...the students who are themselves writing the journal papers. In the question below, I am referencing his time allocations as detailed above.

Tanya: And that is one on one time, where you would be running through something they have written?

Supervisor: Yeah, see the best feedback, the best sessions take place after writing papers, ok. And they can last long, so they write papers, they give me the papers to correct, check, I sit with them after that and we go through it.
But this is for all, even the finalists you would expect that normally you know to be smooth and independent and you don’t worry. ... I take usually only those who have foundation with me in their undergraduate studies, because the research we do is usually highly sophisticated mathematics and the mathematics education in the undergraduate program is limited, so I take only those who have had that knowledge in signal processing and mathematical based signal processing with me. Sometimes they need to go and catch up and attend units, I mean take units in mathematics-that happened in the past.

What is interesting in the above paragraph is the bolded text because it is a mechanism which serves both the Supervisor and student in practice. The Supervisor can begin attracting the student during undergraduate units which he teaches. He can discern at a very early stage the ability of the student, but more so, he can begin targeting them for the final year project. If the students are even remotely keen, they are thrilled to have been chosen by the academic to work with them on the final year project. Interesting also, is that the Supervisor reads everything which leaves the lab. This includes lecture notes, exams, and of course papers. It is a serious breach of the rules to allow anything to be released which the Supervisor has not approved. In the next section I document how students respond, both negatively and positively, to the way the Supervisor manages the access time he affords them.

Chen-Zhao is the same student to whom the Supervisor refers in his disappointing experience related in his story. Recall that the Supervisor summarised the student as dependent, demanding, and disappointed with the supervision he received. Thus, the expectations of neither student nor supervisor were matched in the relationship, leaving everyone involved, including the other students in the group who saw the student as being teacher’s pet, unhappy with the outcome. The Supervisor attempted to meet the special needs of the student, but in the end, he could not write the thesis for him. It is perhaps ironic that now, nearly a decade from the student’s graduation he himself has returned to academia and is supervising students.

The Supervisor reveals quite a lot about his own supervisory style and how he has actually modeled what he does by his previous experience. He reports in the opening sentence that he supervises. Despite his suggestion that this is true, his students seem to indicate he is a supervisor from a distance, a hands-off supervisor. In the following exchange, I clarify this difference, and in the end, the Supervisor recognises and tacitly agrees to his portrayal as hands off.

Tanya: Do you, then, consider yourself to be hands on or a hands-off supervisor.

Supervisor: Before I answer this question, I need you to clarify hands-on, hands-off. I think I know it means, but I need you to be more specific with this question.

Tanya: Ok. Uh I would consider a hands-on supervisor someone who visits the lab regularly, that would have more an open door policy, have more just...expect the students to wander in any time and ask them questions. And a hands-off policy would be a more or less you are only here for a couple of hour’s everyday, and you let the student direct, really their own learning.

Supervisor: OK. I understood, I thought ‘hands-on’ is little different in a sense that I sit with them and you know, almost every day and do things with them, ok, that is what I interpret as hands-on, so I am glad you clarified it. I believe that time has changed my characteristic. I used to be hands-on
supervisor, and I may have become ‘hands-off’ supervisor. Where I started as
Lecturer/Senior Lecturer I used to have a desk and a computer in the, in
addition to my office. So it is not just open door policy—it is more than that,
ok I was part of it...ok, but as duties increased, administratively, and others,
means you do this and that, and travel and so on, so it was very hard to keep
up with that policy, or with that approach, so I started regularising
the meetings and here we have technical meetings, they’re a must, and then you
want to believe that you have done enough. It is for yourself, so that you are
satisfied with yourself. So you think, OK, I have done two hours or four hours
technical meeting, so, of course I have an open door policy, I have always had,
but it is not like it was in the lab.

Despite the fact that the Supervisor claims his small group afforded him time for ‘hands-
on’ supervision, his students appear to consistently report a ‘hands-off’ type of supervision.
Individual students each deal with this differently, as noted here and also in the upcoming
section entitled CARE AND CONCERN.

Student assessment of supervisor style  What do the students make of this style? Do they
submit to it in a display of submissiveness in order to complete? Do they agree? Let us look
more deeply at how the students view the Supervisor. After we consider the view of the
students we conclude that some students have found that the community of their peers, or
APPRENTICE LEARNING, is the true source of knowledge.

To understand if the view of the Supervisor is successful in imparting a great deal of the
responsibility for academic practice and self-teaching to the student, I must consider the angle
of repose of the student regarding the matter of supervisory style. In the following passage, I
further clarify the view of the students with respect to this. From the beginning of
interviewing (see Appendices 1 and 4), I had an open ended question which was posed
something like: What is most disappointing in your current work? I sometimes phrased it
slightly differently, but few words always made it into the question: disappointing, current
work. Tom, a student who did not ultimately complete his PhD, was in a morass: for him,
isolation means drifting off course, delay, and even despair as seen in his thorough responses
to my questions:

Tom: Uhm…it could be just the fact that I ...probably one of the
things, because I am not really working closely with anyone sometimes when I
try or...when I am working through something and it is not working, and I am
not sure why it is not working...because no-one is so intimately familiar or
working with it on a daily basis...you just think...is the idea totally like
wrong...or have I implemented it wrong or...and you sort of start to doubt
yourself a lot more...at one stage, with the thing I was working on in the
communications area, my previous topic, uhm, I had made a very very small
error uhm in some code that I wrote...it was because it wasn’t in the actual
algorithm code, but it was in the code that I used to verify the accuracy, or
whether it was working or not...I did not notice it for probably two months...
and what I finally found ...I happened to be looking at something for
something else...the error, to give you an idea of how simple it was, when I
cut and pasted a line in code from somewhere, I actually pasted it twice...so it
was a duplicate line...and that was all it was...and even when I used to scan
through it and say ‘yep’, that makes sense, that makes sense...because it was
a duplicate line, it did the operation twice and so what I was comparing it to
was sort of the benchmark I was comparing it to was wrong...so the error was large, and it showed the algorithm wasn’t working...once I deleted that line...everything worked just as it should have done the first day...if I had noticed that two months ago I **would be two months better off now.** So...that’s it...and maybe if someone else was working on it...and they have said...we’ll check through that and they might have seen the error or something like that...That is the price of working alone.

Tom’s pain here is tangible, palpable. He admits that he needed someone to check through his code, he implies that some higher authority with more skill might have been able to see the paste error. He seems to imply that his inability to get unstuck was due to the fact that no-one checked through his work. His manner of speaking suggests that he exhaustively checked through the code and the algorithm, repeatedly. Tom was frustrated. He later told me he is meticulous with annotating his code. Even to the uninitiated, two months of delay actually seems astonishing!

It is not unusual for programmers to copy code from other sources, but it would be unusual for a supervisor to check through the code of a student. Rather, if available, a post-doc or near peer might assist. A year later, after Tom had the opportunity to work more closely with the Supervisor and others, he still experiences the disappointment of not getting the level of feedback he was expecting. I asked the following question, which discusses the most disappointing experience, each time I interviewed the students (2003 & 2004). For Tom, the key was the perception of having direct access to someone with relevant knowledge on a **daily** basis.

**Tanya:** Ok, so what really has been the most disappointing thing over the last year for you?

**Tom:** [v lengthy pause] I had hoped to get more feedback and more discussion related to my topic when I went to Great Britain this year, than I had last year because last year The Supervisor was very busy and wasn’t there for very much of the time. This year, Brad Johnson was gunna be around, and Brad has worked in this area, and I would be able to talk and have very high level discussion with him and discuss lots of ideas, but when I got there, it was pretty much, uh, yeah, “I looked at that uhm for a few months, I can barely remember the work so, you can try, but I don’t know how much I can help”, but, yeah, that was a bit, oh ok, disappointing. Uhm, so I mean one of the main reasons why Great Britain was so productive is because there is NOTHING else to do but work, I mean, 7 days of the week, I didn’t watch TV, I didn’t go to movies, I didn’t have any of my friends, I just went to work, so, and there was no real reason for me to go home, apart from just to sleep, so I...that was the main reason why it was productive, I mean there was some meetings and stuff like that, but as I said, you get conflicting advice from your supervisor and that, so it didn’t really help that much. **Uhm** probably the best thing about meetings is it forces you to formulate things in a wrapping up procedure way. Ok if I have been looking at something for three months, then in order to present it to someone else, I need to lay out my ideas in a logical manner from a start to an end, and then explain each of the steps and sometimes the process of explanation brings up more questions which you need to answer, so it helps organise your own ideas in your mind. But the actual feedback that I got afterwards wasn’t so valuable, so I mean, whether I write a report for
myself, or whether I present the information to someone else, I am not really getting that valuable feedback.

Tanya: OK. In terms of the opposite pole, what was the most rewarding thing over the past year?

Tom: Uh [pause] there was a period at the start of the year where uh there was uh a post-doc Piotr Markov and uh the Supervisor asked him to get involved with my project a bit, and even though he didn’t know anything about the project itself, he knew a bit about time frequency and we were having regular meetings and was basically involved me explaining what I understood, and then, he would work out maybe what I didn’t understand or what I thought I understood, but hadn’t proven and he would basically ask questions like ‘oh, what is the relation between this and this’, and I would say, “Oh, I think it is this’ and he would go’ how can you find out for sure? And I said, I guess I could do this, this. Ok, then do it! And so that was good, and even though he wasn’t necessarily telling me anything I didn’t know, he was just helping me to formulate a plan of dissecting a larger problem. There were things which I thought I knew or I partially looked at but not thoroughly until really I chopped it down and looked at each of the components.

Tanya: So that was very valuable time?

Tom: Yeah, I gained a lot from that...

It appears that Tom needs both regular contact and dialogue to test his knowledge acquisition and affirm strategies for moving forward. If I were to summarise Tom’s experience as a PhD student from the above responses, it would be that Tom felt it was a lonely research environment, despite the fact he was surrounded frequently by his peers Yasir, Safwan, Bishr, Dock, Brad and Victor. His most rewarding experience, in that year, was actually getting the attention he craved desperately. The student might be typified as highly dependent. Yasir, equally, when asked about the most disappointing experience, reports.

Tanya: So, Yasir, what is the most disappointing thing that you had happen in your work?

Yasir: The Supervisory arrangements, because let’s say for me and Bishr case, because we change supervisors several times uh actually The Supervisor he, for me, he does not really know what me and Bishr are doing in this area...for he allows the associate supervisor to supervise us but we, both of us, we didn’t receive any much guidance from that...that is why me and Bishr we work independently, so we try to find out the problems in our research and also how to solve this one...that is hard, because like compared to when I was in South Australia, the Supervisor, they really follow what I am doing and then they...if I have a paper they also, they have that paper to have a look...and then later on we discuss uh the problems, how to solve the problem, so actually, the Professor, they really have the time to discuss with the student here...here...we must work independently. That is different.

Certainly, Yasir echoes Tom’s impression of lacking the guidance of a close supervisor, something he had known in the past. In contrast, Mark, and Brad, as seen in a later discussion, recognise the solitary existence of a researcher in the laboratory. He has, however, adopted strategies which allow him to cope with the isolation.
Tanya: To change gears a little bit, describe to me briefly your relationship with your supervisor.

Mark: Uhmm, well my supervisor, sort of tends to uh, uh, tends to give comments once you have done something. So it is very, uh, fairly autonomous in terms of research. You, he suggests a certain topic for example, and you look into that, and you see what you can do. Once you have actually done something, you can show it to him and say “well, what do you think? Is this worth publishing, or is it worth looking further into?”, and he’ll give his opinion and discuss the topic. But he doesn’t sort of along the way, say, work on this or work on that. I mean in my case, anyway, I don’t know obviously how he is with everyone, but it is a more kind of, you do something, and you don’t really go to him unless you have something to show him, in terms of like discussing research.

Tanya: So has it changed over time?

Mark: [clears his throat] Not really, although at the start, uhmm I definitely discussed a bit more with him prior to writing the very first paper that I wrote. Uhmm I would say I discussed more of the basic idea before I went through with rest of the work. Probably since that time, it’s been more once you have done something, then you go and discuss it with him. Probably... what can I do, yeah.

In individual ways, Yasir’s and Tom’s negative statements verify the existence of the model of supervision as the Supervisor himself portrayed it. The Supervisor expects relatively autonomous work and ideas should coalesce in presentations or written work such as reports and conference papers. Tom and Yasir differ from Mark and Brad in their approach to the same supervisory style—Tom feeling isolated, perhaps even deserted, and Mark perceiving the approach as being given autonomy.

In February 2004, after transcribing all of the interviews with the students and the interview with the Supervisor (see Appendix 6—Supervisor Interview Questions), I wanted to test that independence was desired, if not in fact, cultivated by him. To try to discover this, I added two post doctoral students to the proposed second round of interviews. Thus, I interviewed Goran & Brad in December 2004. What do the post-doctoral students have to say about the role of the Supervisor? By virtue of some distance and perhaps retrospection, do they have further insight? The two postdoctoral students in my study are interesting case studies in themselves. Both post-doctoral fellows are within 4-5 years since obtaining their doctorates with the Supervisor. While Goran graduated with a degree in aeronautical engineering, Brad has a double degree in electronic engineering and computer science, prior to embarking upon a PhD in statistical signal processing. I have known both participants since 1996. Brad was a ‘friendly’ participant. He not only answers the questions asked, but gives several thorough and interesting examples. He even answers questions I don’t ask! The interview I had with Brad lasted nearly two hours and provided me with 7,500 words of transcript. Goran’s formal interview, in contrast, lasted only 45 minutes and yielded only about 3,000 words, with exactly the same question set! The transcripts reveal he merely answered the question in the shortest form possible without much supplemental detail, he provided muffled and occasionally inaudible responses for transcription. It was not hostile as much as painful, as the final interchange about the Supervisor below suggests:

Goran: Ok. [laughs, huh, huh] Yeah, well he is always helpful, like when you need, when it comes to money, he’ll support you until the end of your PhD. For
Tanya: What do you think is the role of the Supervisor?

Goran: Well, I think basically he should at least start you off, give you a track to follow which will lead, to a PhD. I mean that is the basic role to make sure you get support when you need it, the basic stuff...office stuff, computers, attend conferences, a bit of technical advice, you know. I don't think he should just give you the start of a path to follow and then as you find your way, he should give you more room to choose what you want to do...cause at the end it is your PhD.

Goran is careful, controlled, even giving multi-meaning responses as in the above highlighted sentence. Does he mean that the Supervisor should monitor the student more after the beginning? Or is it pleasing that the student can choose their own way? However, he does seem to support the view that the Supervisor has a 'hands-off' approach and the student should find and make their own way. Goran seems to be somewhat more like Tom in his desire for direction. Brad, on the other hand, decentres anything that is not related to the technical nature of the thesis:

Brad: Well first of all, I have uh the highest respect for his technical abilities. The thing is, uh, it is not the only thing to consider in a supervisor, but it has got to be in the top three. Uh. So there is that, and I think that is the, mainly the best part of the supervision that he offered me, was the trust I could have in his technical opinion. It is another matter, of course to place that in context. And I wasn't working in something that he was working day to day on. Uh, which is not so unusual. But there are some people who do have that, Chen-Zhao was one of them. Chen-Zhao's relationship would have been something different. Uh, but it is, I did realise that early on, in fact I was, that was what attracted me to do a PhD with him in the first place, the fact that I had the highest technical respect for him. Uh it was definitely a drawing factor. I do know that he is interested in my progression. He does have genuine concern for his students, uh, he is...[long pause]...there is a lot of weight also that he places on long term viability of the research group which is something that uh I personally, I have appreciated. Uh he did encourage a group focus, uh which doesn’t make it wrong, but I appreciate that. I am not sure there is much else to say really.

Both Brad and Goran seem to agree that the provision of a research culture or environment is a major role of the Supervisor. For Brad, technical ability is the number one quality of a supervisor. Certainly, all supervisors in all disciplines must possesses technical knowledge and be able to provide for an adequate research environment. In some labs adequate can mean facilities, such as spectra analysers or scanning electron microscopes. In other areas, adequate may mean access to computers. In reference to discipline knowledge, Brad acknowledges that the Supervisor has his special own niche, and mentions another student, Chen-Zhao, who worked in exactly the same area as the Supervisor: The thing is, uh, it [technical ability]is not the only thing to consider in a supervisor, but it has got to be in the
top three. Brad discusses both technical ability and environment, but doesn’t really share his thoughts about a possible third quality. What could this be? Moreover, how do we make sense of the divergent points of view with respect to the level of direct contact between supervisor and student? In the following section, we see both the reluctance of some to recognise the importance of the team as well as the centrality of APPRENTICE LEARNING in the life of Brad.

**Phenomenon 1 APPRENTICE LEARNING, Discussion**

During the period of observation I came to note that each of the students, barring the newest students, have niches for which they are considered experts. I noticed, moreover, that the expertise was not merely in the technical areas. Some of the expertise related to software or hardware and even to administration. The Australian students were called upon to read papers of the students with non-English speaking backgrounds. One student was known for his knowledge of Linux, another known for his conference poster making ability, and yet another for his facility in tutoring a particular subject. I was lucky enough to be in the laboratory when a new student arrived and I witnessed his apprenticeship to the group. The new student was not shy in requesting information or support from his colleagues, but nor were the more senior students miserly with their time, each very willingly assisting the new student where possible. I wanted to probe this and determine whether the students saw themselves as experts of particular domains. While each had particular skills that others nominated for them, particularly in the areas of software, administration and presentation preparation, all were quite modest about their own expertise areas. Most students made reference to the importance of this pool of readily available knowledge. The importance of having someone very nearby to query basic principles or to ‘bounce ideas off’ was highlighted by each of the students. No student was disparaging of any other student in any way. The following is extracted from my interview with Tom in his first year of study:

**Tom:** To a certain extent, uhm...especially when students start, because I remember when I started and there was Sammy, myself and John, at that point, uh, because there were other people like for example Mark, who had worked in the area that John and I were working in, uhm, a lot of the simple things which some of the first stuff you learn which may take you awhile, you can rely on other people...you can just ask a simple question, and they go...oh yeah, yeah, I looked at that but the basic outcome of that is this...and instead of spending, say, a month to get that point...in five minutes you go...oh...ok. Cool...and then you can progress through that...so a lot of the initial learning steps which normally take a fair amount of time can be progressed through fairly quickly.

Tom’s comment above illustrates nearly perfectly the key strength of apprentice learning...this learning is learning from others in an ambient community, coming closer and closer (in centripetal motion) to the work of a professional. As Lave and Wenger note:

...there is very little observable teaching; the more basic phenomenon is learning. The practice of the community creates the potential “curriculum” in the broadest sense—that which may be learned by newcomers with legitimate peripheral access....learners can develop a view of what the whole enterprise is about and what there is to be learned. Learning itself is an improvised practice:...A learning curriculum unfolds in opportunities for engagement in practice. (Lave & Wenger, 1991, p. 93)

Moreover, students learn also from the war stories the hard lessons of the others gone before them. They come to know what all signal processing researchers should know—the
tacit knowledge of the field. They learn what works and what doesn’t. They practice, in the safety of their house, the writing and presentation of their work in the style required by the international community of signal processors.

While some students lament the regular 9-5 nature required by the laboratory Supervisor, all agree they derive a benefit from the social as well as technical interaction facilitated by a critical mass of students. Moreover, the work of the Supervisor is eased by immediate access of the newer students to those finalists who have been in lab for a longer time. It is a place where pre-professionals learn their boundaries (Traweek, 1988), they learn as much what to say as ‘when not to speak’ (Lave & Wenger, 1991), and ultimately, they learn how to ‘ally themselves with their predecessors, yet differentiate ...themselves in order to establish their work as relevantly new’. (Knorr-Cetina, 1981, p. 125) In short, they learn in practice, a habitus of the laboratory:

...the habitus, the product of history, produce individual and collective practices, and hence history, in accordance with the schemes engendered by history. The system of dispositions – a past which survives in the present and tends to perpetuate itself into the future by making itself present in practices structured according to its principles...is the principle of continuity and regularity... in the social world...(Bourdieu, 1977, p. 82)

In the following discussions I look at whether the students are cognisant of being apart of a community of learners each with different levels of expertise and ability. As suggested by Brad in his story, being in a group of peers is most crucial. This appears to align directly with Scheurich’s archaeology and my concept of webs of significance:

Brad: Uh, I don’t think it is the role of the Supervisor to uh be a boss. I don’t think it is the role of the Supervisor to uh, just pass work down. I think the role of the Supervisor is to guide and to provide insight uh and if necessary to provide technical information, in terms of correcting things. Saying what has been done before or whatever, but I mean the role of the Supervisor is to provide the seed for the work, uh and the initial direction. Uh and also to provide the environment where that work can be done most efficiently. Uh, both in terms of the physical environment, obviously but also the research project surrounding that, can help a research student uh, make the greatest contribution. Uh, and that may mean for example that in successful groups you almost always have peer supervision, where you have your formal supervisor being a little bit more aloof and you meet maybe once a week or maybe once a month, but then you have the more day to day supervision by more senior members of the lab, post-docs or senior PhD students, so that is another thing the Supervisor should provide, that sort of environment where that can happen, because it was never my intention in my studies to try to see my supervisor everyday or every second day. Uh, I don’t think that would have been good use of his time. And to be honest, I don’t think that is what I would have wanted, either because in some respects certainly early on when you don’t have as much confidence, you don’t want to reveal your stupidity too often. You want to minimise that ...

Brad notes that the role of the Supervisor is “…to provide the seed for the work, uh and the initial direction”. After that, the impetus for work is up to the student—who shouldn’t meet ‘everyday or every second day’ with the Supervisor and that day to day assistance should be sought from peers or near peers who are more sympathetic to what the student is going through. The benefit of autonomy is that the Supervisor doesn’t know the limitations of the
student. In Brad’s schema, the student and supervisor keep respectable distances. When I spoke to John, however, he initially seemed to believe the access to a number of talents was trivial, but later admitted that some of the guys are able to help with a number of expertise areas:

John: Well it depends. Quite often, if it is a general question then I will just ask anyone that is around. And if they don’t know they will say someone who does, but uh Dock, Safwan and Tom are involved heavily in uh communications simulations tools. Yasir and Bishr as well. So any of those people. Tom has experienced more of my side as well, so there is interest there, with the landmine. And then Dock has done a lot, obviously, more papers than I have, so he is, ah, he knows that process. Safwan has done the same thing as well, but he understands also the linear systems work and things like that for tutoring work and that, and he is pretty quick with things that he has experienced before. Anything to do with electronics and ways of thinking and some of the maths and so on, Marvan is good with that. And certainly Dock, he has done stats and then Tom, he is very very good with that.

Mark, one of the students in Great Britain, sees the particular value in other students being able to help him pick through his ideas and avoid a trip to the library. Personal experience is privileged over other ways of coming to know. When I consider the story of Dock, in contrast, he would much rather work through the issue himself, find the relevant literature and take from his own experience:

Mark: Sometimes I discuss ideas with Zahir, at least he is in a similar area, so he understands the work, the concepts and talk about some ideas and what is possible, and whether this problem seems reasonable or you know when you get stuck on something, or whether it is just something that has been overlooked or someone offers a new perspective, who works in the same area... well if someone else has more knowledge working in that area, partly by reading the literature, and partly by doing their own research, then, of course they are like a resource as well, like the library. If someone else knows something, the quickest way is to get an answer is by directly asking someone rather than searching indirectly through papers and books and stuff.

In the above passage, I note that Mark is happy to take the shortcut that Dock isn’t. This says a great deal about Dock’s personal way of coming to know something and his desire to solve problems in a solitary way.

In this supervisor section I have considered the Self View, the View of the Students, and how through alignment or in tension, a sense of Apprentice Learning is achieved. Where the tension is resolved via ascension or agreement, Apprentice Learning happens. Apprentice learning, where one learns from and amongst peers seems to be an expedient way of approaching supervision in highly technical laboratory based research.

I suggest that the Supervisor (Osebo) ever seeks to create a network with output as a primary driver. The output focus, as noted by the Supervisor and students appears to be based upon academic inputs and products such as grant writing & teaching, journal papers and conference proceedings. For this, the Supervisor relies heavily on the group. The Supervisor admits his important role in reading the work of the student but also notes that “…you expect those finalists to help the beginners...” Thus, the Supervisor in fact also appears to rely heavily on Apprentice Learning in the laboratory setting. As further evidence of this, the addition of
postdocs apparently supports concepts of maintaining a network; they champion the work of the supervisor, as well the approach the lab utilises. They will also soon become genuine academics; even colleagues. The postdocs also go into industry, and may become a funding source! While this has been a lengthy section, the next four sections; Dock, Zahir, Brad and Safwan all discuss various aspects of studentship. In SOLVING TO SOLVE I refer to the story of Dock. In CARE & CONCERN I refer to two lab members, Zahir & Brad, and in VOLUNTARY INATTENTION I refer to Safwan’s story. These stories fall under the archetype of Mmbora, the hornets who sting like fire.

This section concerned the Supervisor, Osebo, the leopard of the terrible teeth. SHARING was the criteria by which I hope the reader will judge this section. SHARING means the degree to which I was able to imbue the text with believable details. To this aim I have introduced the reader to a number of the characters in the research story, the Supervisor, and several of his students. I have allowed the reader to have access to the exact data that I had access to in the field and in the interviews. I have assembled it to show the reader how APPRENTICE LEARNING happens in the laboratory.
3.2 Mmboro

Next Ananse cut a frond from a banana tree and filled a calabash with water. He crept through the tall grasses, sora, sora, sora, till he came to the nest of Mmboro, the hornets-who-sting-like-fire.

Ananse held the banana leaf over his head as an umbrella. Then he poured some of the water in the calabash over his head.

The rest he emptied over the hornet’s nest
And cried: “It is raining, raining, raining.
Should you not fly into my calabash, so
That the rain will not tatter your wings?”

“Thank you. Thank you,” hummed the hornets,
And they flew into the calabash—fom!
Ananse quickly stopped the mouth of the gourd.

“Now, Mmbora, you are read to meet the Sky God,”
said Ananse. And he hung the calabash full of hornets onto the tree next to the leopard.

Mmboro Introduction

In A Story, A Story, the second goal of Ananse’s quest is Mmbora, the hornets who sting like fire. Ananse tracks the hornets through the African savannah, successfully ensnaring them in a calabash. For the section on students, archetyped by Mmbora, I will refer to Dock, Zahir, Brad and Safwan—the stories which represent the phenomena of SOLVING TO SOLVE, CARE & CONCERN, and VOLUNTARY INATTENTION (play). These are student stories and they are made available primarily in student spaces.

The archetype of the hornets that sting like fire is an adequate one for the purposes of this section which considers social aspects of the question “How is knowledge acquisition driven?” As a collective, the lab hums in harmony, but each buzz is a different voice. In this section, I consider the storied lives of the students, the place they inhabit and co-create. Like the story of the Supervisor, the images here conjured stand as a point in time, a moment. To be a sufficient moment, the working environment, the space, the individuals and their interactions all must be considered. The point of view, indeed the emphasis, is not upon one, but upon many persons, many stories— With many, even divergent, voices. In this section, I am privileged to tell the stories of how students pursue knowledge and the meaning I make of the
The quality criterion of this section is SHARING. As the previous chapter, sharing is the degree to which the stories of the students evoke familiar memories of experience. The SHARING criterion suggests that for the reader to invest belief in the research stories, they should have some knowledge about the process by which I came to know the stories. For this reason, I am again careful to chronicle methods utilised, contributions of the chapter, point of view, time (i.e. moment), data sources and to present significant interview data. The following section highlights three observed phenomena. The first of these, I call SOLVING TO SOLVE, personified by Dock, the second of these, I call CARE AND CONCERN personified by Zahir and Brad, and the final phenomenon, based upon Vygotskian activity theory, I call VOLUNTARY INATTENTION. Taken together, these suggest a possible ‘social axis’—one which is based upon the students’ relationships to each other and as individual researchers. Of course, much of what the reader will note in this section will, in turn, contribute to a further understanding of Phenomenon 1 APPRENTICE LEARNING.

In the first section of the III Analysis I presented two views of the Supervisor: his Self View the View of the Students. These views, from differing vantage points, consider the particular supervisory style, a dialectical tension resolved in the Phenomenon 1 APPRENTICE LEARNING. By contrast, the following section, I present the brotherhood—a system of friendship, support and linkages which assist in creating an harmonic daily working environment, an experiential place not dominated by the Supervisor and which facilitates other work in the laboratory. To really be in the lab, I believe it is important to set the scene for an in-depth investigation into the social dynamics of the graduate students in signal processing & electronic engineering. For this reason, I discuss for the reader the physical layout of the laboratory in Setting, then I move directly to consider Dock, Zahir and Brad. As noted, One fine day is a referent for this section as one can picture the students, moving, or running in the case of Marvan, through the spaces, having the conversations in the cubicles, mucking around in the tea room, or discussing a poster in the seminar room. In Dock, I expand upon the proposed phenomenon of SOLVING TO SOLVE. To discuss the phenomenon of CARE AND CONCERN, I analyse two stories—both Zahir and Brad. While Zahir is a dark and desolate representation of the student experience Brad, on the other hand, felt that he was a contributory and supported team member. But first...the Setting of the scene:

Setting When one speaks of setting, one tends to think of the actual layout of the space or location of the laboratory. My study differs from other studies of labs in notable ways. Firstly, most social studies of science involve laboratories that have significant artifacts. This is to say they involve assays, procedures, equipment and testing facilities which are quite large scale and relatively well funded. Moreover, they do not involve the realm of the pre-professional—namely that of the PhD student. The Lave and Wenger studies are better analogues in that they consider apprenticeship communities, an appropriate model for my work, but they do not consider higher degree research students or scientists per se.

Scholars of ethnography of science and engineering may suggest I have missed Louis Bucciarelli’s work Designing Engineers (Bucciarelli, 1994). While Bucciarelli follows engineers around (Latour & Woolgar, 1986) his study and mine also differ markedly and perhaps highlight an oft discussed schism, particularly in Australian academia. This divide exists between practicing design engineers, and those working in academia. So, while Bucciarelli...
studies engineering design as practiced by applied engineers—those who work in the area of direct implementation of engineering solutions, particularly in industry, my study looks at apprentice research engineers who primarily, but not exclusively, work at the algorithm level. They do little practical implementation in their PhD study. The two types of engineers differ markedly in their approach or method, artifacts or tools, setting or laboratory and obviously, outcomes. Hence, I think it important to detail the laboratory space exactly. For unknown terms, refer to the glossary/word list in the back.

The laboratory is located at a large Western Australian teaching and research University. Organisationally, it falls under a Department of Electrical and Electronic Engineering. The students in the laboratory work in the Department, assisting with part-time teaching, labs and tutorials. Additionally, several of them have undertaken research for grants held by the Supervisor. Physically, the lab is an open plan laboratory space with eleven corner L-shaped workstations—desks which measure approximately 1 x 2 metres. Three partitions separate the space into separate work groupings of 3, 4, and 2 workstations, with an unoccupied workstation in the grouping of four. Two additional workstations are separated by a partition and form an area for a server and a PC plus an additional but unoccupied workstation. Each workstation, barring the unoccupied ones, has either a PC or UNIX ‘box’, depending upon the need of the student. Each student minimally has one locker for books, etc. The lab has a telephone, printer, photocopier and adjacent tea & coffee making facilities and a very small library with conference proceedings and reference books. All students can access a small, shared seminar room with marker board and table and chairs. This also serves as a dining room. This is where I undertook the interviews in 2003 & 2004, and where students go to confer with undergraduate students, supervisors and very occasionally each other, on matters of a technical nature. No further hardware is required by any of the students barring one, but most of them maintain home offices or have laptop PCs or both. A normal day has most students arriving by 9.30 and departing at 4.30 or 5.00.

A newcomer to the signal processing laboratory would likely be surprised by the lack of equipment. Recall though that the students are working primarily with complex algorithms. Tools they use are mathematical modeling and simulation software. As I show in Dock’s story, though, not all the students work only with computers. Dock still works through models of his work with a scratch pad and pencil. Generally all students have a Unix box or Sun WorkStation—box being slang for computer. These boxes are not configured like PC’s but rather like mini mainframes, with the capacity to run simultaneous simulations comprised of massive datasets. In order to do this, students often write their own code using a number of programs including MATLAB. According to its website, MATLAB is:

MATLAB® is a high-level technical computing language and interactive environment for algorithm development, data visualization, data analysis, and numeric computation. Using the MATLAB product, you can solve technical computing problems faster than with traditional programming languages, such as C, C++, and Fortran. (from www.mathworks.com)

There are eight students working in applications of digital signal processing in communications in the laboratory. All of them are full-time PhD students and are in various stages of progress—from new student to nearly completed students. Three of the eight students are Australian and the remaining five are international students. All students have undergraduate degrees in Electrical/Electronic Engineering. As signal processing is heavily based upon mathematics, all students have very strong ability in that area.
In terms of productivity, in 2002 the laboratory of eight students and the academics involved with the lab produced: one book, one patent, one PhD completion, seven journal articles, 13 international conference papers, 23 national conference papers with 34 presentations of both. The group reviewed 44 international conference papers and 20 journal papers. All students received some sort of merit based as well as external scholarships. Via the Supervisor, the group had external funding from national competitive and international grants. The group is called the Detection and Estimation Group or DEG.
Story 2  The Story of Dock

I met Dock in the early Australian Autumn (March) of 2001. He was introduced to me because I worked with a education portfolio in a Cooperative Research Centre (CRC) at Curtin University. Dock was interested in working with one of our researchers, if he was able to obtain a scholarship from us, get permission from his home country, and get one of the competitive international scholarships from the Australian government. He was about to complete a first class honours degree in Electrical and Electronic Engineering from the University of Melbourne. I knew I needed to impress him with Curtin as much as he needed to feel that our place was where he might spend the next four years of his life. I suspected his potential supervisor would have challenged him to excellence in academic endeavours and shown him the lab where the other PhD students, some 5-6 of them were already working on aspects of the research. At that time, not only did I assist in the education portfolio, I spent time fostering the students—most of them were not Australian. As an American, from an American institution, I, like them, was a transplant to Ozzie soil, and perhaps uniquely qualified to provide insights into their potential new home.

I gave Dock a brief tour of the campus and discussed the centrality of basic research in our program. I also gave some information about the academic community and Perth. I asked him his topic. He replied he was unsure yet. These are the sort of students that academics seemed to like best. Tentative students could be moulded to the shape of the research the academic undertakes or in which he was interested in getting funding: the Commonwealth Government (Australian Research Council), private industry, or granting bodies from across the globe.

Dock did get a scholarship from us, but importantly, he received a coveted Overseas Postgraduate Research Scholarship and permission from his government to remain in Australia. He commenced his candidacy in January 2002 and completed in July 2005. I attended his graduation in February of 2006. In fact, Dock was one of the dozen or so students I either recruited or assisted recruiting over the ensuing six years and ultimately saw through to graduation (PhD). His story and mine are intersubjectively linked. I commenced my candidacy in May of 2003 and it seemed natural that I would be involved in the lab with which I was affiliated. I subsequently interviewed Dock on three separate occasions: November 2003, January 2004 (as key informant on writing papers) and December 2004. When the students submitted their theses, my name usually found a place in the acknowledgements, and Dock was no exception.

I came to know Dock as a member of one community: our lab. He was someone who quietly helped his lab partners but who didn’t actively seek leadership or attention. However, over the two years his candidature overlapped with mine, he achieved the acceptance of his work on the Determinant Matrix Lemma. This paper was accepted for presentation at one of the most important peer-reviewed conferences/journals and it formed a basis upon which his thesis was written. One of Dock’s greatest strengths was his ability in mathematics, but he was also particularly gifted in programming using Linux and MATLAB. He completed his candidacy and thesis in a very short time compared with his peers. This has to do with his ability to define an important contribution to the stock of knowledge, get published in a prestigious journal, and suffice other criteria defined by the Supervisor, but importantly, to stay on target. In his first year of study he did some teaching, but after that he became aware that distractions can de-rail the candidate:
Dock: The most disappointing thing...is uhm...disappointing...what I can see...in my experience from PhD is that many things you expect cannot be met in real PhD life and because there are many things you think you can do...and after [you find] that is not going to work. For example, the idea cause you can have a lot of ideas...and then uhm it may not work...or you may not have justified or a numerical issue, or things like that...so it can be very tense. When you are doing work in a PhD...with PhD you have to try and fix...

Tanya: So having your ideas not work is an issue for you, in terms of disappointment...

Dock: Well, yeah, for example, uhm I have heard that when they start doing a PhD they like become very enthusiastic about that and then what happens...not just technical things, but the environment and other things don’t work out and they are very disappointed, they start thinking of leaving the PhD and doing something else, this may happen to many students...which is why...in order to get the PhD you have to take a lot of influence and disturbance and things...

Tanya: And some of those relate to the PhD and some to the environment...

Dock: Yeah, exactly.

The above paragraphs have a number of important points. Firstly, we see that Dock is driven to hypotheses testing and solving numerical problems. He is careful to point out the student must deal with ‘disruption, disturbance and things’. Elsewhere in a question about his preferred work scenario, he responded that he can work intensely, even into the night and stay up simply to solve problems. Ever seeking the answer to whether a student prefers a team environment or an independent one, I inquire as to his preferred work style.

Tanya: So do you prefer to work in teams, or alone or does it depend?

Dock: Most of the time, I work very independently, I work on my own...because I feel that I am more productive when working on my own because ok, I take more time and do it in the evening when I come home or even when I stay up late or something because of some idea so I can spend more time working and writing, but having colleagues working with you also is quite valuable because you can exchange ideas and you can, certainly you can find out something that you assume you know, but you actually you don’t know about...so in that sense working with colleagues in terms of exchanging ideas, in terms of deciding how others work...so in my opinion I mean you need to have both...it is not only myself, or rely on the group.

In terms of exchanging ideas and deciding how others work is actually rather different than having a near peer to assist in getting unstuck. For Dock, the answers are always in writing and in the numbers. For example, I asked him if he ever got stuck, to whom did he turn? He responded:

Dock: If I have a technical question, well normally what I do is that I need to go to the journal articles and textbooks to see what has been done in the past, or even go the internet to check up all of the references. I think...in 90% of the cases they give you the answers all the time. Internet or reading the papers and articles and things. Uhm...and then sometimes I check with Goran and Prof Taza. Goran sends me...he is a fresh PhD so he has a very good knowledge on the area that I am doing, so he gives me like suggestions which I can explore further.

Tanya: And that still is the case...you can still e-mail him and ask him...
Dock: Oh yeah, yeah...well I normally like, whenever I communicate with them, I normally write in a technical report which describes all the things I explore and what I think and then they give me feedback and will explore further. For example, in the submission for ICASSP next year, I propose a new algorithm it was like fantastic, but then Goran suggested me to look at the theory of Kalman filtering, so that I can check whether there have been similar things which were done in that area which we could do better. It was a very good suggestion and I look it up and I found many interesting things.

Yes, I note that he did get assistance, but still, Dock knew his idea was fairly novel.

Tanya: But, yours still was different to that persons’.

Dock: Yeah, mine is still different...in action, I can imagine there are many possibilities that I can do further apart from the original proposal. Very good.

Tanya: Ok. Uhm so do you have lots of simulations.

Dock: Well I always try to keep myself occupied with inventing new ideas and actually when one of the new ideas comes up I just have to try it straight away because if it works then you can try it via simulation...

Tanya: And modeling?

Dock: Most of the time when you first write an equation, the results might not be good because there are many things uh that can affect your uh performance...you may have some bugs in the code and you may spend days and days trying to find out...sometimes they are hidden inside the code and you cannot see it clearly. What happens then is what should expect before you write the code and after you write the code...if they are not consistent, then something must be wrong. It is a matter of debugging...

Note in the above paragraph that Dock cannot rest when he is working towards coming up with a new algorithm, modeling it, and then passing it through MATLAB or some other simulation program in order to ensure the algorithm works. For Dock, the challenges of solving problems, signal theory, mathematical modeling and are the driving forces. In 2003 and 2004 he indicated his desire to continue to do this fundamental research. He notes:

That hasn’t changed. Along the way I discovered that I enjoy doing these things that help me extend my knowledge. Money is not just, [all there is] getting money...making money. To be able to achieve in your career...to do some...to work. Doing PhD is gaining knowledge...it is a bit different.
Dock currently works in a research centre at Curtin University as a Research Fellow. In the discussion following, I explore a problem Dock solved for the sheer joy of solving it, something I suggest is a purely engineering/mathematical behaviour.

Phenomenon 2  SOLVING TO SOLVE, Discussion

Before I spent time in the laboratory, I had often wondered what they actually did, all day, every day. In the Electronic Engineering labs I had known there was nothing to be seen but everyone was always busy. Dock was no exception to this. Like other students in the laboratory, he choose to do a PhD in signal processing because he wanted the challenge of doing highly theoretical work. Like several of the students in the lab, he had an internationally competitive scholarship and an additional scholarship from a cooperative research centre. He joined the group in 2002, and proved himself a productive member with two papers at international referred conferences. He undertook several administrative jobs as well as teaching in 2002. As evidence from the interview data, his career goal is to pursue engineering research. As with all the other students, he likes to know how things work and when he was a young boy he took apart and rebuilt electrical things like radios. I demonstrate how Dock also has quite unique capabilities. In this section, I look specifically at the more solitary endeavours of the students. I clarify the phenomenon of SOLVING TO SOLVE, and how this is an important bridge between solitary and social learning.

Dock spends solitary moments of his days reading, solving equations, debugging simulations and writing. The following are three pages from his work pad—a pad of paper that he keeps near his computer mouse where he works through ideas numerically:

![Figure 3, N minus 1, pages 1 and 2]
This is common in the laboratory and is essential to the thinking process. In the case of the above optimisation problem, Dock discarded the sheets after he had transferred the relevant data to a technical report entitled *General Solutions of Quadratic Matrix Optimisation Problems*. Dock had worked on the problem after discussion with others in the laboratory. This is typical of technical discussions where a student pursues an idea with certitude and actively seeks to prove it. Dock’s three page technical report finalises his assertion he tested on paper, and later in simulation. He concludes:

> It is revealed that the optimisation problem could have a number of solutions. However, it is still not clear in each case whether each solution corresponds to the local or global minima/maxima. This is best done by computing all possible solutions and comparing them numerically.

Many students feel challenged by unsolved problems – and like detectives on the trail of a criminal, they will not rest until that equation is solved, regardless of the relevancy of the equation to their personal research. The discussion between Safwan and Dock occurred after Dock had solved the optimisation problem above:

**Dock:** Oh, by the way Safwan, I solved that problem [indicating the “show your work pieces of paper, as above]. These mean we have N degrees of freedom. But it should be N-1, right? Z here should not be in the subspace of x—when you differentiate the signal.

**Safwan:** This is orthogonal to x

**Dock:** No, no, no. V is orthogonal to y. Z here is to the subspace of q, which is orthogonal to y.
Safwan: I’ll have a look at y.

Dock: V should be in subspace q....that is the solution...see...

Safwan: Yeah, but v is any here? It is one of the solutions. You can put a constraint.

Dock: It is actually N-1

Safwan: You can try with simple example and see how it work.

Dock: Yes, but we need to be explicit.

Safwan: Did you do it for work or just mathematics?

Dock: No, I will probably throw it away.

Safwan: Dock dot com

In the beginning part of the dialog, Safwan was unconvincing, ready to start plugging in examples and constraints to test the idea. But, Dock is very serious here. He says “Yes, but we need to be explicit”, which seems to me to say “you can try all the solutions you want, but make the case. I did, and it is N minus 1”. Safwan plays off the solution, seeming to know that Dock often just mucks around solving: “Did you do it for work or just for mathematics.” Here I see work, thesis writing, juxtaposed to mathematics (fun)! The drive to create and solve complex mathematical problems is perhaps exclusive to highly mathematical disciplines such as physics, statistics and of engineering. Dock reported to me, as did other students, a compulsion to think of new approaches to problems. He emphasises: Well I always try to keep myself occupied with inventing new ideas and actually when one of the new ideas comes up I just have to try it straight away because if it works then it works ...then you can try it via simulation... Simulation is modeling on the workstation using MATLAB for example, as described above. Dock uses both MATLAB and C+ for simulation on the computer. Students have to write the code to test the equation as well as the equation itself. Debugging the code, Dock notes, is process in itself:

things can affect your uh performance...you may have some bugs in the code and you may spend days and days trying to find out...sometimes they are hidden inside the code and you cannot see it clearly. What happens then is noting what you should expect before you write the code and after you write the code...if they are not consistent, then something must be wrong. It is a matter of debugging...

The MATLAB simulations can consume hours, weeks or months. One student, Tom, had a bug in his MATLAB code as noted previously. He spent two months working out where the error was when the simulation did not perform as the numerical model did. In the end, the error was a duplicate line in the programming code in MATLAB. He had spent so much time writing the algorithm to be tested, that the duplicate line in the MATLAB code went unnoticed.

It is rather normal for the student to ‘work out’ the idea numerically on paper as Dock did on the N minus 1 example. If results appear significant, the idea usually is transferred to a typed technical report. In the above case, Dock did utilise the results despite indicating he would throw the solution away. The reports are still personal documents, records of ideas
explored, but they may not necessarily be shared with others, according to Dock—much in the way that authors write for practice. As noted, after numerical modeling, the students will likely model the algorithms using MATLAB or C+. Only after an algorithm has proven consistent in the numerical model and performing well in MATLAB simulation will the student then consider it worthy. Should the algorithm function well in simulation, the student may show it to others in the lab and finally the student may consider showing it to the Supervisor. Dock’s work above in solving the optimisation problem and Safwan’s statement about “Doing it for work (read thesis) or math (read fun) support the theory that the students are generally driven to SOLVING TO SOLVE. While Dock solved the problem in a solitary way, he shared the solution with Safwan. Hence I see the knowledge transfer, even of a trivial problem, from one student to the next, and importantly that the justification came along with answer. The next section will consider the phenomenon of CARE AND CONCERN. For this, I shall consider two stories— Zahir and Brad.

The criterion by which this section is to be judged is also the SHARING criterion. This is the degree to which the reader can confirm that, for instance, complex algorithms are worked out on paper, modeled, and then simulated using a program such as MATLAB. Keen mathematicians will recognise the desire to work problems just for the pleasure or drive to work them, much in the same way writers will write simply to test some word patterns or evoke some imagery.

**Phenomenon 3 CARE AND CONCERN Introduction**

**CARE AND CONCERN** as a name for the third phenomenon was derived from the concept of duty of care which I came to learn about both as a working ethic in social research as well as in academic research management. It is a term which I first heard in Australia. How the students looked after one another suggested they felt a moral obligation, to show one another an ethic, a duty of care. I certainly did not expect this from the outset, so the social interaction of the students struck me initially as quite unusual. I expected that the lab would be silent most of the day, occasionally punctuated by whispered conversations of a technical nature. What I found was a lively lab where verbal interactions are punctuated by periods of silence. The verbal interactions are not whispered technical conversations but normal tone of voice conversations – generally of a technical nature but matters of a personal or administrative nature are also discussed. It is not unusual for people to shout over the partition to others, nor is it unusual that people make normal tone of voice personal phone calls on either mobile phones or on the shared telephone. During technical discussions, usually raised by one student physically going over to the desk of another student, it is rather common that the student who was asked would then draw in another student who may have complimentary expertise. In this way, discussions draw the interest of most of the students, occasionally resulting in lively exchanges involving over five or six people. Technical conversations are moved to the seminar room only occasionally and seemingly only when the markerboard is required for illustration, most typically working through long algorithms.

Daily, most students stop for lunch from 12-1 pm to eat in the seminar room together, as noted in *One fine day*. Several students bring their lunches and two of them consistently shared their food with others—whether it was fruit or an international dish which many had not tried. Those who do not bring their lunches will often pick-up lunches for others so that only one student will need to leave the lab. The lunch break lasts approximately 50 minutes and generally, though not always; conversation is of a non-technical nature. Events such as getting a paper accepted, passing candidacy, birthdays, engagements and other life events are
celebrated with cake supplied by the celebrator. Weddings, babies and departures such as graduations are celebrated with a gift to which all of the students contributed.

I noted on at least two occasions students using library identification cards of others, ostensibly, as they had maxed out the limit on their own library card or needed access to another institution locally. Equally, two students routinely offer to collect mail, located in another building, for the others. Those students with cars will take the others on errands of both personal and professional nature and it is common that a student leaving for a lengthy period will loan their car to the others for their use.

An example of concern for one another is the missing man phenomenon. As in family groups, where it is very common for siblings to determine the missing person and try to discover or account for his or her whereabouts, it was routine that students would know where their colleagues were but not by any formal mechanism such as a chart or notice board. Rarely would my queries about students’ whereabouts be answered with “I don’t know”. Equally, after about 10.00 am each morning, if there was a missing man, one of the group would begin to query this with the others to determine if concern was required. Toward the end of my observation period, I fell within the house rules and arrived at 11 am one day—two hours later than my usual 9.00 am. One of the students noted immediately; “We were beginning to wonder where you were.”

I found the camaraderie, the care and concern that each of students showed one another was like a brotherhood, and the laboratory served as a house for their interactions. It might be inferred that the Supervisor or ‘father’ of the house commanded both respect and fear from the students. He provided a model of a lab (house) and leader (father) from which the students (sons) might later break away as mature researchers, yet seek to emulate or replicate. When asked about the group being like a team, one member of the group commented:

Yeah, pretty much, I mean uh...it is a nice social environment. We all interact fairly well socially uhm being part of a team I guess is also feeling like you belong to a group and because we are always in here together and we do talk a little bit about work, it is not a very structured academic team where we are all working on the same project and we all have same goals, and when one person sort of moves the project ahead, everyone is moved ahead...it is not like that...but yeah, you do feel like you are a member of group.

After significant discussion and analysis of the stories of the Supervisor and Dock, which I illustrate Phenomenon 1--APPRENTICE LEARNING and Phenomenon 2--SOLVING TO SOLVE, I have reason now to support a theory that the students have a caring, intimate brotherhood in which they feel their knowledge acquisition needs are attended to. Is this true? Is the socially situated environment of the apprentice learner sufficient for the proper growth of the student? In the story of Zahir, I show that he retains a morose disposition which no amount of social inter-activity will disperse.
Story 3 The Story of Zahir

Zahir is the only person I know who is fluent in five languages. By fluency I mean read, write, speak: Arabic, French, English, Russian, and German. If that alone should qualify one for a PhD, Zahir should at least one have one PhD, if not two. I would like to say he is the most gifted of all the students in the laboratory. I would say that, but I don’t know him long enough and he would not want me to say that about him. He may not want me to actually even be writing about him.

Zahir’s story will be shorter than the other students because Zahir’s expectation of the PhD does not seem to match with the Supervisor’s idea of how to manage the process. In fact, as I evidence, Zahir has the impression that his wishes for his PhD experience were completely ignored. In this way, Zahir did not feel that there was CARE & CONCERN for him; for his desire to complete in a timely fashion, to have his degree be relevant to industry. In an e-mail to me in June 2007, Zahir lamented:

It's more and more difficult. Nothing really happens. I dislike this lab more and more and feel less and less connected with it. Through my applications, I am realizing how much time I've been wasting. To be frank, I don't even know where to look anymore. I can't believe that after so many years, all I can hope for is some low-profile, short-term, pathetic post-doc.... actually, even that seems difficult... I guess our lab's reputation is not that great. Thanks for your support. I really appreciate that. I always thought of the US as a destination, but the problem is always a security-administration issue.

I am Algerian... I cannot hope for more than a 'J1' visa, meaning that I will have to leave as soon as my first contract finishes (say a post-doc). The age requirement is also against me. Great Britain seems to be the slowest place on earth and people don't mind staying in uni for 20 years... but elsewhere, I am pretty much disqualified. I have nothing to offer to a country like the US, where so many skilled and bright people arrive at a very young age. In addition, it seems that a British degree isn't worth much outside the British system... there is nothing international about it. That's the feedback I'm getting from the employers. We'll see what happens.

It seems that Zahir has the general impression that he had very little control over several aspects of his time as a student, and indeed in his future. In the interview data below, from 2004, I asked Zahir how much influence the Supervisor has over certain areas of research such as: Planning, Problem Solving and Practice.

Zahir: I mean I did that ...In terms of practice, uhm, well my orders come from him in terms of administration, I mean yes, I will put it this way, I would not have any initiative administratively, I would rather avoid that.

I don’t want to be involved in admin, but I have to, so that whole comes from him. Teaching, same thing, I mean, uhm, I am now third, fourth year already (rising intonation, like question) like I am halfway through almost my fourth year, and I am doing teaching. If I had the choice, I wouldn’t do any. But yeah, I mean this is a requirement, he is in charge of the lecture, I am just an assistant, I am helping him a lot, I have to do it, but that comes from him. Uh he defines the topic, the outline of his lecture and so on, I mean, I may, I might contribute with a different, uh problems of the tutorials, but with the tutorials itself, presenting it, marking and so on, but yeah, but I don't have more influence there, it is all his, it is his domain, if you want.
Writing...uh, whell, he proofreads every writing here, everything, whether it is admin, teaching or research. I mean anything that has got his name on it, he reads it. Uh I mean, we do have to put his name on it, he is the boss. You see, he is like the one who owns the research topic, if you want. Uh, yeah this is all, in terms of practice. Now in terms of problem solving, work monitoring, yes he was, uh not always directly, but yeah, he is the Supervisor, I mean uh, somehow, if you want, whether it appeared clearly or not, but uh, I think it is the same for every PhD student who all think yeah, he is the safety net. No matter what we know, there is the Supervisor; whether we feel his presence all the time or not, it doesn't really matter we [know] he is there. Concern about the research progress...uhm...yes, he is aware of the timeline, yes, but I don't think there were any problems that made him intervene directly. Uh apart from that, yes, uhm, my objective which was to finish within a certain time frame may not seem, cannot represent the same priority to him, he might consider that I am still with him in the long [run], so it was never an issue for him, uhm.

The bolded text shows Zahir’s feelings of being controlled. Zahir does not see one area of his student life which the Supervisor does not influence, from papers, to teaching, to administration; it seems almost as a big brother watch-dog. The final sentence actually confirms that the student believes the Supervisor has no concern whatsoever about the needs of the student to complete in a timely fashion. In fact, he is bold enough to say that the reasoning is that so the Supervisor can continue to use the student for teaching and administration. In saying ‘...we do have to put his name on it’ does Zahir mean that even when things are originally the work of the student the Supervisor will also lay claim to them? This ill-will continues in the following paragraph which hints that the degree itself is not even relevant for industry. The above e-mail came at a time when Zahir was looking for a position and was having a difficult time due to his age. A year later however, as I demonstrate from further e-mail correspondence, that he finds happiness, truth, in industry. For the interview in 2004 I try to get him to project to the future.

Tanya: Ok. Good. What is your most probable employment after you have, you get your PhD?

Zahir: I don’t know. Now, usually people who do PhD right, it is like the shortcut or the most indicative way, actually the entrance to academia, so it is an academic position that people target after a PhD, traditionally. Uh, my personal wish would be to leave academia, and I did not do, I did not engage in a PhD for academia, I wanted a degree to move to industry. I wanted to use it as a shortcut in industry. Now, there are constraints. Uh, related to my age, related to the job market, uh, so I know that there is the possibility of staying in academia, but I will target industry, and I will see. Now, in industry, for people with PhD’s the most logical place is the R & D department, but I also don’t want to spend a lot of time in R & D. I mean R & D is interesting, it is certainly good, but I don’t want to dedicate my career to research and development only. Uh, I would like to be a bit more uh, how do you call it, I would like to have a wider, uh vision of industry as it is related to daily life, to the market, if you want.

I don’t want to be just involved in the technical aspect of it. Uh the PhD, the degree, at least in the beginning. I thought it would...[break in tape] In Great Britain it seems that most technical PhD’s find employment in industry, at least they all go to industry. They might come to academia, but I haven’t seen many doctors who pursue academic careers directly, so in Great Britain that seems to be more natural or standard. Now there is also the push on whether I want to stay in Great Britain or not, which a priori, I don’t want to.

It would be difficult to be more negative about ones prospects than the above.
Tanya: Ok. So uhm, what is the most valuable skill you will bring to the job you want to get after you leave, that you got in your PhD?

Zahir: Uh, yeah, I think it is the notion of design, which is basically offering new concepts, it is the way of approaching problems, the way of modeling different situations in order to solve a given problem, so it is basically a way of design. This is basically the way an engineer...it is a lot more important than a specific skill and a specific uh specialty or anything like that. Personally I don’t want to stick to a given specialty anyway, if I can have like a methodology that can help me move from one area to another, then that is something I consider.

Zahir foreshadows a later topic I discuss in reference to innovation. I wanted to know what the students felt was THE most important rationale for completing the PhD. I noted that to get a job in industry in Great Britain, one must have a PhD. In Zahir’s case it is really the concept of design; a methodology, a schema to explore, develop and translate the unknown to the known. The following question was asked of all students to see if they might have changed tack during the

Tanya: Uh, if you could go back to the beginning of your PhD study, what would you do differently and why?

Zahir: Uhm, I would have certainly inquired about the perspectives offered by a particular group, I mean what can I gain by doing this particular program of PhD? There are different groups, different ways of doing things, different outcomes and perspectives, I mean that I would have uh, checked more carefully. The other thing I would have planned things more carefully. I would have been more cautious with time. It is really the planning, I could have done it a different way. Easily.

Zahir is now taking a bit of the blame, at least perhaps for not checking other groups when he was looking for a place to do a PhD. Also, he blames himself for not being more cautious with time. But, as we shall see in the blog entry below, we begin to question how Zahir was actually recruited. We see that he may have been promised something which was not, in fact, delivered.

Tanya: And so given your goal, do you think the PhD itself could have prepared you better? Like would you have taken any industrial secondment or business units during the course of your PhD?

Zahir: Uhm. Well I am targeting industry, uh, yes, I mean, especially if I don’t want to spend all my life in a technical field. I mean, yes, targeting management, all the aspects, yes, I would have applied for any courses, support courses or specialised programs uh that would diversify my profile, management, project management, business administration, I mean these are very interesting issues. The only concern is time. Uh, now for industry, is PhD the most optimal way? I am not sure, it is a choice, and it is a vision. My vision of uh industry, was yeah, I mean PhD can help you do a lot of things. It was a shortcut. I mean I worked in industry before, I mean, my short experience convinced me that a degree, or at least a program where you learn about concepts and a strong methodology, was, I mean you have time to think to think about that methodology and you dedicate time to that methodology, it takes so much time. Whereas when you are involved in the real life activities in industry, you are taken by those activities. So you do routines. You do evolve eventually, but it might take 5 years, 6 years before you move to a certain position, whereas a PhD gives you already the framework. All you need to put in there is the main details relating to specific environments, car industry or whatever. You do have plenty of time to think, I mean you already thought about different scenarios. You are trained in conceptualising things. Whereas while I was in industry, I had to fulfill tasks and there are a lot of them, and you have to be profitable and so on and so on before you reach a certain stage maturity in this industry. You have to spend some time, and you don’t have time to think. That is the thing. Whereas in a PhD, you are asked to think a lot, that is the thing!
In the above paragraph it appears that Zahir may have appreciated the chance to have management units, but he quickly reverts to what became a standard statement that the time in PhD should not be taken by “fulfilling tasks”. It should remain in the realm of deep thinking and conceptualisation. Surely the irony of the delay in his timeline with the teaching and admin noted in the beginning of the story didn’t escape Zahir? Note again that Zahir returns to focusing on the importance of having that needed time to learn to conceptualise the methodology.

Phenomenon 3 CARE AND CONCERN, Discussion 1

In the above story of Zahir I show that despite a number of conditions held constant, ie supervisor, project type, lab camaraderie, the student seems to retain a rather negative impression of his experience. In his interview in December 2004, he recognises that delay was brought upon by his time being devoted to teaching and administrative: [The thing is] that up to 50% of your time can be uh, dedicated to the University, that includes teaching, administration, and some oriented research. Now obviously, any extra work which is research or teaching or anything, requires time…it did give delay [to my timeline]. Moreover, Zahir doesn’t see the relevancy to his other goal of having a ‘shortcut’ to industry:

Zahir: I think that we are a lot more fundamental than most British groups who are in the same area who tend to co-operate a lot closer with industry, and particularly British industry, so they tend to do a lot more advanced development, applied research, whereas we are more fundamental, academic style research.

In the story of Zahir and the discussions so far, I note Zahir is somewhat careful not to dip deeply into an abyss of negativity. The following blog entry, however, leaves nothing to the imagination as to Zahir’s real feelings. Though it was posted anonymously, I have reasonable suspicion that the entry is from Zahir. This is due to the tone, writing style and grammar. While it is nearly perfect English, the words are chosen carefully and the order is somewhat different from a native speaker of English. The blogger uses the following opening statement: Through my opinion, I which is exactly the same construction and choice of words as the third line in the e-mail, as highlighted, which was sent to me and is a part of the story. It also touches exactly on the themes Zahir mentioned he is particularly unhappy; namely the lengthy time to complete, lack of industry relevance and lack of job prospects. Let us consider the blog entry exactly as it appeared in December 2005. It is indicated in pink to differentiate it from the stories.
The four important traits of a supervisor are:

1. Technical/discipline ability
2. Provision of environment & culture for research to happen (included internal/external)
3. **Please supply YOUR third choice**

Please comment on your agreement with each of the above criteria, and if you wish, the degree to which you received it in your PhD.

**posted by Tanya at 6:42 PM on Dec 10 2005**

**Anonymous said...**

Blogger 1

*Through my opinion, I hope to contribute to answering the last two blog questions. I try to express a true concern which connects the PhD with reality. I don’t want to add nice comments on how interesting research is and how I learned things and so on. Repeating theoretical ideal comments about a PhD is useless and would not add any new element. So what is the PhD for? What to expect from a supervisor?*

Beside all what has been said, I think that the long term perspective is important and helps measure the success or failure of a PhD program. The PhD program is not an objective but only a means to more important goals. Therefore, if the PhD does not help the students reach their goals, it cannot be seen as anything but a failure, no matter what the final grade is.

When individuals decide independently and not as a result of marketing to start PhD studies, they are normally not students like others. They are adults with ambitions and perspectives. These PhD students expect that their views are at least taken into account. They cannot be simply treated as juniors serving the lab policy. Ignoring this fact inevitably leads to disappointments. If the Supervisor, who is responsible for leadership, cannot establish a positive partnership, the result will be negative for the student. It is obviously not as dramatic for the Supervisor who in the most optimistic case, often remains unaware of such repetitive dysfunctions.

Like in any institution, the Supervisor or leader must prove strong abilities in the field of interest. This is even more important in science. Superficial supervision can be a waste of time and money, with negative effects on the long run especially after the PhD.

A supervisor must be a leader not only because of his seniority and authority, but more for his vision and ability to establish a true partnership with his staff. Not all PhD students see their future in the vicinity of their supervisor’s environment. A good supervisor should be able to guide such students to a favorable situation. Not all supervisors are able to deal with their students’ ambitions. Supervisors should also accept that not only their ambitions matter. There are thousands of labs here and there, but not all are of the same quality. Students realize this fact quickly and may retain a final and general negative idea about their research experience.
A supervisor and his institution must evaluate the level of satisfaction of their staff more often and more carefully. The offers available to their graduates on the job market and their evolution is an indication of the weight of the PhD program that these supervisors have led. If some supervisors take this factor into account, they may decide that their success is very relative.

The student’s responsibility is to choose carefully the PhD program that best corresponds to his or her perspectives. New students have the right to ask all sort of clarification from their future supervisors. There is no default. Just like the students who must satisfy the Supervisor’s academic requirements, the Supervisor must honestly provide all guarantees to take the students’ concerns into account, especially regarding their post-PhD plans. If necessary, prospective students should contact other PhD students related to the lab, especially former graduates. It is not difficult to see from the paths followed by former graduates the likelihood that the student’s own objective may be attained.

11:43 PM

Anonymous said...

Blogger 2

In my opinion, the third trait of a supervisor could be his personality and ability to communicate with the PhD student. A good supervisor is not just a supervisor. A good supervisor is also a friend, a colleague.

12:46 PM

Anonymous said...

Blogger 1. Following previous reasoning, I would say that friendship is neither "necessary" nor "sufficient" and is different from one person to another. What’s more essential objectively: Supervisor’s friendship? or good job offer?

10:07 PM

Top of Form

You can use some HTML tags, such as <b>, <i>, <a>
as a different user.

The blog entry raises a number of issues. Let us consider the first bolded section. Blogger 1 notes there is no objective or evaluative mechanism for measuring the success of a supervisor. He suggests that job offers (for students) would be one mechanism, and if the Supervisor took a good look in the mirror, he might also realise there could be a deficiency.
The reader begins to get the impression that the Blogger feels he has absolutely no degrees of freedom; that there is no greater authority to whom to appeal. Next, let us consider the additional bolded text. Although this may be the subject of further inquiry, that Blogger 1 may have even been misled about his prospects for the future. He notes: “...[the Supervisor] must honestly provide all guarantees...especially regarding post PhD plans”. Did the Supervisor fail in doing this? Did he oversell?

Blogger 2 notes that friendship might be a possible third important trait. I note that Zahir had suggested that the Supervisor had kept a kind of family, in Perth, but possibly that had changed in Great Britain:

Zahir: I think that Prof Taza tries uh to maintain a very relaxed atmosphere, very friendly atmosphere, I mean back in Perth already he was trying to build up like this kind of family atmosphere, I mean yeah, the relationship is pretty yeah, open, I would say. Uh, it goes sometimes even beyond the scope of technical uh investigation or whatever. Uh, yeah, he shows support as well, at least whenever it was possible. Uh. It is true that generally speaking he did change a bit because of the requirements of the British atmosphere. The environment is a bit different here and umh the system works very hierarchical.

Blogger 1 firmly and swiftly refutes the illogical conclusions that friendship is an important supervisor trait as postulated by Blogger 2. He suggests that even friendship is considered neither sufficient or necessary when it comes up against the potentiality of a bad job offer. Friendship, whether it dissipated in Great Britain or not, is valueless.

What I take away from this, if it is conceded that Blogger 1 is Zahir, is that he utter rejects the notion of supervisor CARE OR CONCERN for him. It seems a kind of nihilistic approach to any value that could have been imparted from the experience in the laboratory. However, Zahir successfully defended his thesis in Great Britain in 2006 and received his PhD. He currently works in industry in Great Britain. If Zahir represents a nadir of student experience, in the next section I consider the other end of spectrum, Brad. Brad’ experience is a zenith, almost diametrically opposed to Zahir’s. Remember that both students had the same supervisor. Both worked in Perth and then in Great Britain. Both were supported financially by the Supervisor for the entire time of their affiliation with him. In short, and to re-iterate, many variables were constant, but the experience ended very differently. Brad has a positive general attitude, though he also experienced significant disruption both personally and professionally as he was progressing through the program.

In the above section about Zahir the reader has a rare glimpse into disempowerment and discontentment felt by the student. Zahir may retain a final and generally negative impression about his research experience. If, in dwelling on the blog entry, along with the interview data and the e-mail information, the reader is able to experience the tangible pain of the student, the sense that the student was not well looked after, then the data, the stories have a high degree of confirmability. The data comes up the same from several angles of repose; blog, interview and e-mail, and all tell the story about the participant’s feelings. If the reader believes the above are true stories and information about Zahir, then this section has a high degree of SHARING.
Story 5  The Story of Brad

Brad walked into my office one day in January 1996. He was wearing a ‘Bananas in Pyjamas’ t-shirt with both B1 & B2 on it. The Bananas are children’s stories characters brought to televisions around Australia by the Australia Broadcasting Company, a public television company. I was a new employee in the department and Brad was a new PhD student, having just graduated from Queensland University of Technology with a double degree in computer science and electronic engineering. I remember the T-shirt better than the reason he was there to see me. Anyone who was his age, at that time his early 20’s, and wore a B1 & B2 t-shirt was pretty comfortable with themselves. So began a friendship which has lasted until the time of writing. And during his tenure with the Lab, the Supervisor supported Brad with scholarships, international exchanges and eventually a post-doctoral appointment. In turn, Brad provided the Supervisor continuity, attracted and fostered students and undertook research and writing and computing support, especially in website and network setup. As I noted earlier, Brad has respect and admiration for the Supervisor’s technical ability and desire to ensure the viability of the group. The Supervisor facilitated Brad obtaining a position in industry in 2006, a position he continues to hold. In the following story I highlight the ‘care’ component:

Brad: Uh, but it is, I did realise that early on, in fact I was, that was what attracted me to do a PhD with him in the first place, the fact that I had the highest technical respect for him. Uh was definitely a drawing factor. I do know that he is interested in my progression. He does have genuine concern for his students, uhm, he is…[long pause]…there is a lot of weight also that he places on long term viability of the research group which is something that uh I, personally, I have appreciated. Uh he did encourage a group focus, uhm…

Brad was actually instrumental in fostering a sense of home, of care in the lab. He frequently organised activities outside of the laboratory including meals, sports such as volleyball and squash, and holidays on weekends. He also would assist new students in getting oriented to the community, both on the campus and in the community. Intangibles such as these take an inordinate amount of time. I noticed Brad seemed sensitive about his length of time to complete. He was not alone in this—as we saw in Zahir’s story previously. However, Brad’s impression of one of the great values of his supervision is that he was left to be relatively autonomous, supervised essentially by peers in the first two years, as noted previously and below, again, to emphasize:

Brad: …it was never my intention in my studies to try to see my supervisor everyday or every second day… I don’t think that would have been a good use of his time. And to be honest, I don’t think that is what I would have wanted, either because in some respects certainly early on when you don’t have as much confidence, you don’t want to reveal your stupidity too often.

Brad’s ideal of working with a more senior peer is in sharp contrast what he observed with Chen Zhao, who had daily and lengthy contact with the Supervisor—“Chen-Zhao was one of them. Chen-Zhao’s relationship would have been something different.”

In the first moment of my thesis, I undertook a benchmarking exercise by traveling to the US. The point of this was to see if it was possible to teach innovation. As it happened, my Alma Mater (undergrad and masters), the University of Illinois at Urbana-Champaign had such a program offered at the undergraduate level. See: http://www.techmgmt.uiuc.edu/. They actively foster dialog between engineers and business majors; bringing the two groups together for classes, seminars, projects and capstone units. Other universities have jumped on this bandwagon, note for example: Massachusetts Institute of Technology, Stanford and University of California - Berkley, widely recognised as being amongst the top five (along with Illinois) engineering colleges in the US. Hence, I asked all of the students and post-docs in the interviews if they felt their education in the PhD program could be enhanced.
Tanya: Ok cool, so given your goals, do you think the PhD could have prepared you better? Like would you have done some other kind of industry secondment or maybe some business units or anything like that?

Brad: Uhm never having worked in industry, I am speculating here but uhm, I think especially if you looked at a 21-22 year old PhD student, I can’t see the benefit that we would get from a lot of those things. I think the normal career path, and the logical career path to me that I alluded to before is to start off technical, get seniority, get depth of understanding and overview, and when you get that depth, then you start to need these non-technical skills that really become useful. But I think even for a PhD graduate, when you are starting off, you should be doing your PhD for technical, because you want to learn a technical problem, at least in the short-term. Now is there anything else I could have done to prepare me, sure, yeah, I learned a lot of things sort of on the job, that I could have been better prepared for, uhm and we did...this was my own circumstances, being forced to do IFN 001 in Queensland University of Technology, was information retrieval skills. It was a whole week course on how to use the internet. Uh, being taught by a librarian who probably learnt it the year before, teaching it to engineers who had been using the internet for 4 years. Uhm...a huge waste of time...but, something, if it had been taught properly, it would have been useful because I ended up having to learn some of those skills, not talking about subjects, some of those skills from peers, and you know, being taught how to read and write. I mean at Chalmers the graduate students, they are given the option of doing a unit on academic writing and it is full semester long course. And there you are thrown into that with other people, it is a technical university, but from all other fields and so you are learning the generic skills of academic writing and I don’t think I was ever taught that and dread to think of reading over the first paper that I wrote.

In the bolded text, Brad indicates how he makes use of peer learning from the larger lab in order to help him learn the engineer’s writing craft. He notes that the Swedish University, Chalmers, actually provides a technical unit on that. In terms of writing, I found that Brad didn’t write a full paper at all during his time as an undergraduate:

Brad: For me, I did the DeSPA submission based on the work that I did in undergrad. That was submitted after I started as a PhD student. But that didn’t mean I could write. It took me a month to read my first paper. To write my first paper, it took me a couple of months, whereas now it is, if I have to...I can...

Tanya: Crank it out...

Brad: Exactly. Uhm and some of that is experience that you can’t learn, but, there must be a better way to prepare students for that because then it comes down to the group that you are in, and I was lucky that I was surrounded by, day to day, peers who I have the highest respect for and who, who have those skills, and I was lucky that I joined the group that had some of the signal theory part of the group was probably about a dozen people and at least ten people when I joined. Uhm, I know people who are first year PhD student who are practically by themselves. That would be hard, and I think that given the proper support mechanisms to, to help give anyone a grounding in that would benefit a lot of people.

The above texts raise a number of key points. Firstly, it is important to remember that the Australian PhD model is not, in fact, a US model. Students will rarely, if ever, take coursework units. Only where a student is working in an area perhaps not covered in the undergraduate work. Brad, in fact, took a higher level math at the University of Sydney in the first semester of his PhD. So, it would not be normal for students to want or even be allowed to take units in other disciplines, even writing units. Secondly, Brad admits he needed assistance in “being taught how to read and write”.

Even as an undergraduate engineer, he did not write. This would be completely atypical in the social sciences and humanities in Australia, and most tertiary institutions in North America. This is because those disciplines in Australia use written communication in the form of papers and, equally, most testing would be essay based, unlike engineering. In North America, most engineers, even at the undergraduate level, have at least one required core communication unit which instructs on fundamental writing and communication skills in the discipline. Brad admits that it took him one month to read his first paper. Papers in engineering are complex. As noted in the previous section, the apparently methodical production of papers which seems a default to the Supervisor, belies a manufacturing process which is not evident in the text. As corollary, reading them for the first time is an equally magical deconstruction process. The Supervisor in my study normally gives the student a paper in the first weeks of their study and instructs them to understand it. What is meant by this is that the student must actually reverse engineer the steps taken to construct the conclusions. The student must run the simulations, work all equations for himself, must chase the references and must understand deeply how the author of the paper came to their conclusions. The Supervisor will test the students understanding of the paper after the student agrees they understand. In this way, the student learns the process of replicating research, a foundation of science and engineering, and the Supervisor discovers, through dialog, the intellectual ability of the student.

Finally, Brad notes how important it was when he joined, that there were a dozen other students in the lab that were working on signal theory (highlighted text) above, and importantly, how difficult it would be if one was alone. It is not, however to his near peers to whom he turns; it is only of value if the other student has significantly more experience in research and writing which is of benefit to Brad. It is my understanding that where possible, Brad later also became a valued member of the student group, as he was ushered, so he ushered others into research, writing and lab practice. He is autonomous and positive about his affiliation with the laboratory and knowledge acquisition. He is positive that his knowledge base will be ‘useful and a good grounding’ as he works in a technical area, a chosen application.

Tanya: Ok. So where do you hope to be in 5 years?

Brad: Uhm. In industry, in a position where, probably less pure research but still a research component. I would still like to be working at some sort of technical level, but I would expect and hope that it would be a little more uhm higher up. I don’t expect to be coding every tiny little algorithm that I have in mind, but I would hope that I would be part of a group in industry and that I would be have recognised expertise in that industry for that particular occupation. Uhm...that I am not just a purely theoretical person...that is what I would hope that I that I learn and develop over the next 5 years. I would expect that a lot of knowledge that I have so far will be useful and a good grounding, but uhm I would hope that I really and truly in the next five years get insight and expertise in a chosen application.
Phenomenon 3  CARE AND CONCERN, Discussion 2

In the previous discussion, I showed how the student, Zahir, approached his experience in the laboratory. This section represents CARE AND CONCERN, in a different light; where Brad retains an open and positive perspective of his experience. His story, and analysis, is presented directly after Zahir’s in order to contrast the differing angles of repose. Brad’s personality is somewhat different from Zahir’s. He is a social person who retains a network of friends from his time working in Sweden and also in Great Britain; opportunities which were both presented to Brad by the Supervisor in this thesis. Before Brad worked with the Supervisor in this story he had worked with another supervisor. It was a difficult time and it seems it would have been easy for Brad to give up on the PhD entirely. He did not choose to do so as seen in this discussion.

Brad: Uhm, whether that was the right decision in retrospect, I am not sure because a year later, then, those issues came to a head and uh I did end up changing supervisors and it wasn’t uh...a happy move...[the previous supervisor] did some things and said some things to people about me that I wish he hadn’t, and that I think were very, very unfair. Uh so, at that stage, I uh was extremely unhappy, but fortunately, I wasn’t alone at that time because there were others, the move to this new group wasn’t done just by me, by myself, because the Supervisor was leaving the centre as well and he was taking his two students, I think it was at least two students at the time, that were actually his students, officially, plus myself. Officially, I wasn’t his student, but in practical terms was, and other students followed shortly thereafter. ...but overall, uhm I my memories of my PhD time are extremely good. I think it is, uh, I don’t regret doing it, I don’t regret the choice that I made to do it straightaway rather than working for a couple of years at DSTO. A very good friend of mine did end up going to DSTO and uh chose that path and he has done extremely well for himself, uhm. But I don’t think that given the information and the choices that I had, and the maturity that I had, I don’t think that I made a wrong decision at the time. Uhm so I don’t have regrets in that respect, but overall I thought that the lifestyle that I had during most of the time that I was a PhD was very nice, uhm, financially you are not paid a fortune, but as a single guy with no mortgage, no kids or anything like that, I was living very well.

Brad was one of the first that left the old supervisor and changed to the Supervisor of our laboratory. Brad later moved with the Supervisor from Brisbane to Perth. Within two years of getting his PhD, he was back with the Supervisor in Great Britain for a post-doc, which is when I interviewed him. The Supervisor assisted him in finding a secondment in Sweden, and later, a one year appointment there. In turn, Brad supported the Supervisor in many ways I have already noted in the story. Despite the problems with the first supervisor, despite the moves and changes, Brad and the Supervisor experienced a kind of mutual patronage. Brad shows no indication of the neglect Zahir seems to suffer. On the contrary: he actually recognises that he has been looked after, not only by the Supervisor, but by his peers as noted previously:

Brad: He places a lot of weight on the long term viability of the research group...and I was lucky that I was surrounded by, day to day, peers who I have the highest respect for and who, who have those skills, and I was lucky that I joined the group that had some of the signal theory part of the SPRC was probably about a dozen people and at least ten people when I joined...
The dialectical tension viewed by juxtaposing the self-view of the Supervisor of his supervisory style and the view of his students is echoed again here. I contrasted the divergent voices of the students—Zahir and Brad. As a researcher I must continually attend to the voices of participants. I cannot simply privilege one voice over another, or silence one because he didn’t suit my theory very well. The information that has been presented in the stories which represent the phenomena of APPRENTICE LEARNING and CARE AND CONCERN is information that chronicles the complexity of human relationships—and those humans, try as I might, cannot be made to speak in a way they would not. This cannot be over emphasised, especially when dealing with engineers. For, as much as I try to understand them in one sort of way, a solid definition has eluded me. In my next section, I suggest a concept of play as it constitutes the social system created by the students themselves. The phenomenon is illustrated by the story of Safwan, who embodies VOLUNTARY INATTENTION.

The criterion by which I would like this section on CARE AND CONCERN to be judged is SHARING or the degree to which the reader hears the clarion voice of Brad as he believes he has been looked after, how he did not appreciate the required IFN 001 class, how he didn’t want to look silly in the eyes of the Supervisor, and looked to his peers to help him with technical matters such as writing. If the reader is able to believe that Brad has taken away an overall positive attitude that he has been well looked after, then this section has a high degree of verisimilitude or SHARING.
Story 6 The Story of Safwan

The story of Safwan centres on VOLUNTARY INATTENTION, or play. Safwan, as we shall see, was frequently the instigator of a plethora of work intervention strategies: chatting, talking on the telephone, jokes, funny noises or statements, interesting websites, pranks, send-ups, annoyances, controversies, problems and countless miniscule diversions and humorous capers. In the story below, I present a few of the pranks and conversations which involve him, the other students, and occasionally me. In most labs I know, in either academia or industry, or have studied in the literature, the role play is a central and pervasive. This story would otherwise have the potential to characterise Safwan as being an atypical buffoon, rather than the affable, gentle, but somewhat nutty researcher I think he actually is. It should also be said that Safwan was genuinely liked by everyone, but whose research was thought of as lacking rigour and discipline. I cannot judge the truth of this as I have weak technical knowledge of the area. However, at the end of the story, I present a transcript of an event where Safwan presents his work to his peers and supervisors. The Supervisor’s highlight publicly Safwan’s lack of attention to detail.

Safwan received his PhD in February 2006 along with Dock and Marvan. He had successfully passed the formal requirements for the degree and the informal ones required by the Supervisor. He went on to work at a research centre in Perth. The following incidents occurred during a normal day in the laboratory. If one glances through the “One fine day”, one will notice a ‘play’ break just at 3:45 and then Safwan’s discussion of his visa problems at the end of the day. In this, several people choose to give him advice, which he takes by admitting: “OK. Guys...it is always me...just do your work...I am disturbing every day. Sorry...sorry”. In the following sentence, I am trying to determine any changes in the laboratory since part of the group went with the Supervisor to Great Britain. Thinking I would get information of a technical nature about the loss of expertise, instead Safwan reports the following:

Tanya: Going back a little bit, you did mention Mark & Zahir & Goran, how has their absence in the lab affected your work, necessarily...

Safwan: Maybe more sometimes,

Tanya: Because they stimulated your thinking?

Safwan: We used sometimes to joke to talk it is a kind of refreshment. I mean you can’t think the whole day...you cannot work the whole day, so while you are sitting thinking you find someone like giving you an impulse or something (laughing)...you joke with them, so it is good. I mean it is, it annoys, but I feel it is not bad because they are your close friends, you may spend the weekend with them, you have to relax, go out on the weekend. I go home, and I go to my train, my tank, my house, my car. Sometimes my car is fixed, but I just want to double check. I can’t work...really their absence does not effect me so much.
Safwan’s ‘train, tank, house’ all refer to his car and he refers to working on the car even if it is fixed—an activity which we can assume the others also assisted. If we read between the lines, in his spare time he tinkers around on his vehicle. He would be aware that some others, like Dock and Marvan, work long hours and even on weekends at home, on their theses. But the important statement here is that Safwan realises that his personality can become somewhat of a disturbance—but he’s ok with that because you cannot work the whole day and it is a kind of refreshment and they are your close friends. While he claims their absence did not affect him, the reader might think otherwise.

The pizza number

In the story below, we are all playing with Safwan because he seems always to have status or visa issues. The people in the “pizza number” are, Marvan, Safwan, Dock and I. We formed a small node separated by partition walls from the others. The national number for the pizza company Dominoes (131-888) is one number off from the then Department of Immigration (131 881). Note the little play with Yasir’s and Marvan’s name at the beginning of the dialog.

3.40 Safwan: You know the IFFT ...the inverse fast fourier transform? Well you can apply the M-A-R-V-A-N. Yasir to the power of N = nlog Yasir...did you know that?

Marvan: You should finish your PhD soon and go or you will drive us crazy.

Safwan: There is a dictionary there (online). It is really good.

Tanya: Ok, look up dialectic.

Safwan: Dielectric?

Tanya: NO! not dielectric...dialectic....

Safwan: Spell it.

Tanya DI (thinking I am going to be silly) MARVAN!

Ha ha...(they all laugh)

Safwan: Tanya, did you know that the pizza number is one number off from immigration?

Tanya: No. Call them!

Safwan: OK. [calls Dominoes then, apologises for calling them and says the number is one number off from the immigration number]

Tanya: You should have ordered a visa...delivered.

Marvan: Or a classic Italian...

We all laugh.

I depart. 4.50
In the pizza number, we see people becoming equations \( n \log \text{Yasir} \) or below, we see them becoming websites “Yasir dot com”. In Optimising the Solution, we hear another math term applied to an everyday occurrence. Dock Van Damme is a name given to Dock by Safwan, and one which seemed appropriate at the moment.

**Optimising the Solution**

In the text below, Optimising the solution, I show how Dock, like Safwan above, applies mathematical principles and jargon to a situation. We admire Dock for his quick wit, rather than his quick reaction time to the spilt water.

14 August 2003

1.05 *We return from getting lunch and go to the kitchen to it heat it up. The others are heating their lunches. Marvan spills the drip catch on the water cooler which happened to be full. Dock just stares at the big puddle. I grab paper towels to sop it up.*

Tanya: Dock Van Damme, why didn’t you jump into action?

Dock: *I am still optimising the solution.* [Marvan, Safwan and I burst into laughter].

Later that day when all is quiet in the lab, I can hear frequent beeps. Someone’s mobile is losing charge.

Safwan: Yasir.com.au
Safwan: Is that yours Bishr? It is going to die. That is not good for your battery.
Bishr: No, it is better.
Safwan: I don’t think it is better
Bishr: [Says something...inaudible]
Safwan: Ok, nickel cadmium

10.15 *Yasir moves to the phone or to look for something.*

Safwan: Yasir.com.au

Observation: I find this incredibly amusing, but I don’t laugh. No-one laughs. It was merely a silly statement

Safwan makes a business of using people’s last names as in the above Dock dot com and “Yasir dot com”. He says this frequently for no apparent reason whatsoever. I didn’t hear him say Tom, John, and Saif or himself—Safwan dot com. The pranks are common as we see in the analysis. Safwan seemed to enjoy interrupting and being interrupted. He is widely recognized as one of the best teachers of linear systems and digital signal processing and is very often the ‘go to’ person for teaching issues because he was rated highly by his students, whom he enjoyed helping and didn’t mind being interrupted by them.

Frequently Safwan will get calls from his friends who will need rides in his car or for other reasons. One of his good friends, Muhammad M, calls on a relatively frequent basis for a ride or assistance with family issues. One of our Thursday afternoon endeavours once was finding a hotel for Muhammad’s brother and family who were coming to visit. Of course, I didn’t mind such interruptions, but I am worried that it might upset others in the lab as we called five or six hotels in the King’s Park area.
While it was tolerable in the space of the laboratory, and afforded a break in the otherwise full day of sitting at one’s computer thinking, mucking around was not tolerated by the Supervisors. Illogical thinking as well as unstructured presentation of ideas was immediately and fervently dampered. The following was one of two presentation incidents where Safwan did not apparently prepare his written or spoken presentation. The first time that this occurred, Safwan did speak to me about it in the interview, however he asked for it to be held in confidence, hence the transcript cannot be entered here. However, the situation was not unlike the situation below, witnessed by many.

**Observation:** Today all of us are presenting our work. We each get 10 minutes talk with five minutes for questions. We are told this is **strict**, because in conferences it is important to keep to time. The session begins at 10.05 with an introduction by Rajan.

10.10

Dock reported his work over the last six months. He has worked in four areas:

- robust stationery theory
- numerical algorithms
- extension to asynchronous CDMA
- detection strategies

Dock finishes his presentation and questions by 10.25. We have 10 minute break.

10.35 Safwan begins his presentation; he cites his Professor as the Supervisor at the School of Electrical and Electronic Engineering as his supervisor.

**The Supervisor:** Safwan, sorry about this. I am not your supervisor officially. Also, there is no longer a school. It is a department.

Safwan begins. In the last six months he details how he has undertaken a comparison and modification of some model selection procedures. He has considered data models & objectives, decision models. He shows his simulation results which are graphical data.

Dr HLH asks for some information. The Supervisor follows on with a further query: If you are doubling parameters, then backward elimination is to remove non-significant regressors. On complex value regression you cannot use real data. I don’t think it is a safe [model]. What about interchip interference?

Safwan answers and continues, showing another graph of a particular aspect of his work which is new. He is getting very nervous now, visibly frustrated.

**The Supervisor:** I have a problem with this...this peak at 25 has disappeared when you run your other model.

Rajan: Yes, the scale has changed.
The Supervisor: Yes, I know.

Safwan: This is something new here.

HLH: Yes, but your double peak is almost one full peak and it should not disappear...it is not MAI?

The Supervisor: Safwan, you are entering into too many model selections. You should look at non-integer delay values. You have to have performance, but the relevance of the problem is in non-integer delay values. In this we can estimate the number of users—utilising non integer variables of the sampling period. Finally you will estimate the number of multipaths.

OBS: Safwan, visibly shaken at the public remonstrations, is clearly unable to speak and merely stands there.

The Supervisor: Safwan, o.k. just go on.

OBS: At 20 minutes (10.55) many people were getting unsettled. We knew that Safwan had not much effort into cutting down the size of the talk to fit the time. This was obvious.

Safwan concluded at approximately 11.00 followed by several additional questions from both supervisors. The remaining students, including myself presented their work. Following this, we went for lunch at a campus restaurant. Then on the way back from lunch, I told Safwan that he looked really, really sad. He reported to me that he was a bit, and that if we hung back from the group, he would tell me. We did this. He said to me that he felt that the Supervisor thought he was stupid and did not have good ideas. I told him that the Supervisor took me apart at my discussion as well. He said that he heard the Supervisor once talking to Zahir and he thought they used an Arabic word meaning stupid. He thought this had referred to him. I told him that I did not think that the Supervisor thought this, but rather that the Supervisor wanted to help him. He said that he knew what the Supervisor was questioning him, but did not answer because he did not want to say anything.

To delay, I remember that I left my mug in the seminar room, so I go to the department with him to get it. I illustrate on the board about how there are really good students and really bad ones and ones in the middle. The really good ones don’t need that much help. The really bad ones are not worth the help, and the ones in the middle take all of the heat. He said he understood, but I thought he was not paying attention to me. So, I repeated it verbally as we walked back. He made me swear I would not tell anyone. I thought he may have overreacted, actually. I am glad he got it off his chest, though.

While no one can begrudge Safwan his refreshment at the lab, it would have been more beneficial for Safwan if he could organise his work and presentation in order to communicate to his colleagues his ideas in a little more systematic way. I have heard that when he presents a paper, his style is much different and he presents very well. It is possible that he didn’t take the laboratory seminars as seriously as he undertook conference presentations, or that he was well coached just prior to conferences.
Phenomenon 4 VOLUNTARY INATTENTION Discussion

In the previous three phenomena APPRENTICE LEARNING, SOLVING TO SOLVE, and CARE AND CONCERN I demonstrate a tangible intensity. The stories are rich in detail. The students and the Supervisor take the work they do seriously and as such, the seriousness is reflected in their stories, if not moreso in the intensity and differing points of view as noted in APPRENTICE LEARNING and CARE AND CONCERN. In the next section, I show how students break the intensity of thinking, programming and debugging by VOLUNTARY INATTENTION or play. This phenomenon is illustrated by Safwan. As I show, it was not unusual for students to choose not to work or to exchange expertise or information relating to research, teaching or administrative matters in a playful manner. In this section I discuss the theoretical underpinnings of play in work and illustrate an additional play incident Cake! from the lab.

With respect to the theoretical underpinnings of play in work situations, Lave and Wenger (1991, p. 111) note of apprentice quartermasters that “...distinctions between play and work or between peripheral activity and other work are little marked”. For the main, however, the role of play is rarely discussed in the context of adult learning. Like Lave and Wenger, I noted play merged into work or vice versa and that it is real and important, indeed integral, activity in the laboratory. Play provides a place or playground away from the intensity of scientific and engineering work, but also establishes common ground between otherwise diverse, and perhaps competing, groups of people.

While exploring the notion of play, I came across the work of the soviet psychologists, particularly Vygotsky, who analyses play as crucial to childhood development. Vygotsky (1979) postulates that as a child develops, his/her natural attention is mediated by adults and teachers surrounding him so that by adulthood the child has gradually gained both voluntary attention (volitional acts) and involuntary attention. To extend this and based upon my observation of learning in the laboratory environment, apprentice learning similarly involves segments of play that I call voluntary inattention. In interpreting Vygotsky, Lee notes:

Play is of critical importance in Vygotsky theory because it is through play that the child develops the uniquely human forms of motivation...Play becomes the ‘leading edge’ of the child’s psychological development because it allows the child a ‘zone of proximal development’ through which both new motivations and new kind of attitude toward reality are created (B. Lee, 1985, pp. 89-90)

It is precisely this zone which is a place for the PhD students to develop and continually renew the personal relationships upon which the motivation for further inquiry is based. Because students feel free to muck around they equally feel free to express their opinions and query their colleagues about technical matters. They are less concerned about peer judgment or fear of sounding stupid. Students tell stories or jokes, often at the expense of one of the others. Equally, as I have shown with Safwan, they may break out of a period of intense study by drawing attention to something interesting or thought provoking on the internet or in a book. Jackson notes:

The existential imperative to exercise choice in and control over one’s life is grounded in play. If life is conceived as a game, then it slips and slides between a slavish adherence to the rules and a desire to play fast and loose with them. Play enables us to renegotiate the given, experiment with alternative, imagine how things might be otherwise, and so resolve obliquely and artificially that which cannot be resolved directly in the “real” world. What we call freedom is founded in our ability to gainsay and invent, to countermand in our
actions and imagination the situations that appear to circumscribe, rule, and define us. (Jackson, 1998, p. 29)

Jackson further notes that “to do things in one’s own time and in one’s own way, to think of the world as something one creates, as well as something of which one is merely a creature…” (ibid). The meaning in this is essentially that in order for normal development to occur, the student must have a locus or space which is totally their command, where the order of things and ground rules are defined completely internally. This is exactly why ‘pranking’ each other is fairly common, with the minor theft of a key, book, or backpack (lunch!) among the more common pranks. The following illustrates a prime example of this pranking behavior and one which was relayed to me.

---

**Cake!**

Marvan: How was the cake, Safwan?

Safwan: Marvan, you and Dock owe me cake for this.

Marvan: Safwan, you know you should bring cake. Did I tell you Tanya the joke we played yesterday?

Tanya: No, what?

With glee Marvan reported the following story:

At lunch time yesterday, I say to Dock—“Dock brought a cake today. It is his birthday.” Dock, not missing a beat, says “Yes, I brought a cake”. Later, in the kitchen, Dock and I set the joke in motion…I point to a cake box from last week…when Rajan had his celebration. There was only one piece in it. We agree that ‘cake’ should be at 4.00 pm. I go back to the lab and tell everyone there is cake at 4.00 pm. Near 4.00, Dock goes to get the cake box, and places it on the table. I bring the plates. Safwan then has everyone come to the table, including two lecturers, Rajan and Raheem. Safwan notices that there are no spoons, so says to me “Marvan, you did not bring spoons.” Safwan then goes to get spoons and serviettes. When he returns, I open the cake box…to reveal one stale piece from the previous celebration. Everybody got a big shock, but some thought it was funnier than others.

Marvan reported that as Raheem left, he said “I knew I should not have trusted you, Safwan.” Marvan then frankly admitted to me that Safwan was furious and later he got revenge by taking Marvan’s backpack, which meant that Marvan could not bring lunch from the next day. Pranking behaviour suggests the comfortable status of those older students who had enough history with one another to determine the others would not mind the prank or the time it might consume. This suggests a brother-like behavior. Jackson notes that the objects used in play, such as the cake in the example above, ‘...enable the users to distance themselves from relations which have become perplexing and anxiety provoking. As ‘objective correlatives’ of these relationships, they provide us with simulacra that we can manipulate in order to recover some measure of autonomy.’ (Jackson, 1998, p. 31) In this, Jackson means that in joking and play, the students can return to a place of common ground.
While the technical and social conversations are a diversion, a refreshment, as Safwan says, for all of the students at some point in any given day, it is interesting to note that of the eight students only four of them have headphones and usually only two or three students will wear them regularly. The presence of headphones indicates whether the student is able to continue working with diversions. Students without headphones were also more likely to participate in impromptu discussions.

The students regularly spend out-side of laboratory time with one another—going to lunch, movies, sports, clubs or occasionally to an organised barbeque or sporting event. Lynch, writing about brain researchers:

More consequential was how lab talk arose from within a taken for granted set of common experiences which were not available to an outside observer. These experiences included not only the historical course of researches that members had accomplished in their work, but also names and accounts of objects, persons, and events which were not directly featured in the context of research. These were referred to in stories, jokes, references to past and upcoming events and talk of non-present persons. (Lynch, 1985, p. 166)

So I show, both in laboratory life and with our engineering researchers, play is a requisite function. Certainly, in stories told by the veterans in industry, play is also important—items and space provide an “objective correlative’ of relationships which provide a simulacra that can be manipulated in order to recover some measure of autonomy.” (Jackson, 1998, p. 31) Play or the phenomenon of Voluntary Inattention, is an integral part of most properly functioning labs and workgroups. This no less true of adult learners as it is of children, and it may be especially true in information and data rich research, where there is precious little in the way of mechanical activity in which to get a break from the screen and deep calculations. It is also true in industry, as I discuss later.

In this section, I have attended to some of the lighter moments I experienced in the lab. Does the story of the pizza number conjure a lab space where the students are free to express themselves, where they can feel they can ask questions, stumble, make jokes? It is a place where common ground is experienced and renewed each day in play. If the text of the stories about Safwan allow the reader to know Safwan as a fallible, but otherwise likeable force in the laboratory, then this section has been successful in contributing to the SHARING criterion.

The next section considers the final archetype I employ, Mmoatia. She is associated with innovation and the phenomenon of the Manufacture of Knowledge as well as my own story as a researcher in innovation.
3.3 Mmoatia

Ananse now carved a little wooden doll holding a bowl. He covered the doll from top to bottom with sticky latex gum. Then he filled the doll’s bowl with pounded yams.

He set the little doll at the foot of a flamboyant tree where fairies like to dance. Ananse tied one end of a vine round the doll’s head and, holding the other end in his hand, he hid behind a bush.

In a little while, Mmoatia the Fairy-whom-no-man-sees came dancing, dancing, dancing to the foot of the flamboyant tree. There she saw the doll holding the bowl of yams.

Mmoatia said: “Gum baby, I am hungry. May I eat some of your yams?”

Ananse pulled at the vine in his hiding place, so that the doll seemed to nod its head. So the fairy took the bowl from the doll and ate all the yams.

“Thank you Gum baby,” said the fairy. But the doll did not answer. “Don’t you reply when I thank you?” cried the angered fairy. The doll did not stir.

“Gum baby, I’ll slap your crying place unless you answer me,” shouted the fairy. But the wooden doll remained still and silent. So the fairy slapped her crying place—Pa! Her hand stuck fast to the gum baby’s sticky cheek.

“Let go of my hand, or I’ll slap you again”—Pa! She slapped the doll’s crying place with her other hand. Now the fairy was stuck to the gum baby with
both hands, and she was furious. She pushed against the doll with her feet, and they also stuck fast.

Now Ananse came out of hiding. “You are ready to meet the Sky God, Mmoatia.” And he carried her to the tree where the leopard and the hornets were waiting.

Mmoatia Introduction

In the previous four sections, covering the four phenomena of Apprentice Learning, Solving to Solve, Care and Concern, and Voluntary Inattention I have, like Ananse, gathered a number of phenomena together. Illustrating these phenomena thoroughly has resolved tensions which exist between student and supervisor, morose and content student, and intense research work and “play”. In A Story, A Story, clever Ananse managed capturing both Osebo and Mmaboro but Mmoatia was a far more elusive prize. In pursuing Mmoatia, the fleeting fairy, Ananse must speculate accurately the exact location he will find her, and ensnare her ingeniously.

I have captured a view of Osebo, the Supervisor, and Mmaboro, the students, but I have yet to capture my prize...innovation. Like Mmoatia, innovation is not only illusive, but a truculent and demanding muse. In a sense, the graduate students and I seem never to quite grasp her, but together she is our focal point and ultimate goal as researchers. How do we, as students, innovate? Is the output of our research effort—our papers and articles, innovation? If no, what is the relationship of the Manufacture of Knowledge to innovation? At the very least, the phenomenon of Manufacture of Knowledge produces papers, journal articles, conference proceedings and other printed translations of research work. To explore what, precisely is meant by the Manufacture of Knowledge, I ask four questions about manufacturing knowledge: How? What? Why? And For Whom? The referent for the phenomenon is Karin Knorr-Cetina’s book and concept “Manufacture of Knowledge: An Essay on the Constructivist and Contextual Nature of Science.” (Knorr-Cetina, 1981)

I have shown the spaces where the students are working on maintaining a social Ecology—where they are in relation to their supervisor, or to the other students, or just playing. When they are actually creating, engineering, researching, what do they do? The largest percentage of engineering student work relates to the production of journal and conference papers and conference posters. These activities are as important to engineers as ‘writing—a method of inquiry’ (Richardson, 2000), is to qualitative researchers.

Research writing in engineering and science is no more or less naturalistic or representational of the actual research process, than research writing in education. Each is choreographed, with forward and backward passes through the data. As such, I accept the proposition that papers are a construct of intellectual activity which, though important, are hardly an exact reflection of how the science or engineering of the thing actually took place. Because the research process of teaching oneself what one doesn’t know is much the same in all disciplines, I use my research story to illustrate how one can effectively cross the border into another discipline and essentially make intellectual forays if lessons are learned properly. This will further serve to contextualise the Manufacture of Knowledge.
Story 7  The Story of Tanya

Close. Month end. The Profit & Loss statement will be due in Paris in a few days. Tempers flare, staff work 12 hours a day, accruing, collecting, chasing, calling. Thankfully, I am not one of those staff members—I am on the other side of that door. This month we took losses at about $1,000,000.00. There was usually a lot of profanity—“You’ve had the fucking boat at the dock for the last three months...couldn’t you have done the work then, Jesus Christ!” Those were the kinds of tirades that came more frequently at close.

I laid low. I didn’t speak to anyone who didn’t specifically address me. It was better for me! Since I started in August the previous year, a dozen or so people were termed. There were weeks when we termed staff who had been with us for eight or nine years. Termined was the word for terminated. Did “terminated” make it easier to say—easier than say “fired”, “let go” or maybe “your career with the Company has been executed”? Termined is certainly a euphemism. Coming from academia, this execution process appeared harsh. I tried to save people who looked like they were headed for termination. I even tried, when I could, to help them improve their performance, or to suggest to the Company that they weren’t holding the threatened employee to the same standard they held others. In at least one instance, I was successful. But later I was involved in a termination. Lives were at risk, I rationalised. I still remember her face as she cleared her desk. Industry, in just a few months, had certainly changed me.

Within one month of my hire date at the Company, I was asked to write up a brief discussion of a tool the company had fabricated and used at a jobsite in the headwaters of the Mississippi in 2005. The tool had to be used at a depth of about 30 feet of water, but had to accommodate the client’s welder to seal a pipeline repair in a dry environment. This was a client specific requirement. Over the course of the next few months, I explored all I could about the new technology; who was involved, how it came to be, etc. Our abstract was due in January, and if accepted, the full paper was due in March 2008. My colleague and I worked on the abstract and it was accepted for full submission by the end of the month. The writing was on! I found that the standard mechanical engineering paper in this area had the following sections: Abstract, Keywords, 1. Introduction, 2. Nomenclature, 3. Problem Presentation, 4. Proposed Method, 5. Results & Analysis, 6. Conclusions, Acknowledgements and Bibliography. Ah, but that looked familiar. The guys papers with whom I worked in the lab had a similar structure, which I dissected in my thesis. I had other projects on, many, important projects, so the work of writing up the paper came sooner than I expected. At one stage I was running between the diving supervisor and the engineer and one of the junior divers who worked on the project and I even asked divers who didn’t work on the project.

What were the limits of the pipeline company that required a specialty solution? What was the dredging like? Why did the habitat have to be in three pieces...back and forth between the drawings, field notes, diving supervisor. Not a day passed that I didn’t need to speak to the diver or the engineer. At one stage the engineer admitted “With all the changes, in the end, the project took longer. And you should have seen it—I didn’t think it would work—I mean I thought it would leak or buckle. So, it was so misshapen we had to heat treat. "That was because of those divers, pointing upstairs. “Don’t write that”, he told me. When I spoke to the diving supervisor he remarked “Yeah, Archimedes down in engineering couldn’t work out that issue. You know why we call him Archimedes don’t you?” And so the sniping went on...
Within a week of the due date to submit the paper, I came to be working on one of the concluding chapters in my thesis. At one stage it all became clear, innovation (commercialisation of ideas) was not something you could teach or learn in a classroom. The innovation with the clamp came because of the many little and not so little compromises made between the practitioners divers and engineering and fabrication. It was about compromise, collaboration and communication—not about solitary research with no drivers other than the quest for knowledge. This realisation, as simple as it might seem, struck me so that I did, at that moment, begin to cry. The Eureka moment I had sought for my entire thesis came to me in such a serendipitous fashion that I was not expecting the impact it might make at the moment of collision.

But, not to miss my moment, I later said to the diving supervisor. “You know what innovation is?” He replied “What?”. “What you and Mark and Adam and Todd did with the habitat” I replied. “You had an idea and you sketched it on a napkin and then you worked with the client and back and forth with engineering and fabrication to get it right. I mean that is what innovation is. It is about collaborating with a meaningful purpose.” “Yes. I want to show you something” he said. I followed him to his office and he showed me a PowerPoint from corporate. “You see they want us to try to teach people to be innovative.” “But you can’t teach it.” I said. He replied “I know, and I am not going to try.”

The paper was submitted and later accepted for presentation and publication in the conference proceedings. The final reviewer comments: “Excellent paper…it will present well at the conference.” And the second reviewer “Journal quality.” At that moment, when I read those comments, I was sitting in Toronto, working on my thesis. I didn’t know which was the greater achievement—knowing innovation so intimately, or being able to write about it so succinctly that I could get published or that I did what I actually set out to do in the beginning —cross the border from my life as a researcher to a life in the engineering world.

Subsequently, the paper was presented in 2008 in Calgary at the International Pipeline Conference, and, in fact the company won an award based upon the paper and contribution to the environment. It has subsequently been converted into an article for the general pipeline and gas industry. (Vernon & Erickson, 2009) This essentially illustrates that once one learns some basic principles of production of texts and has access to essential data, one can cross the border into another discipline. Of course, one must be nimble enough and savvy as to the best location to do the crossing, but my foray into Mechanical Engineering does illustrate that it can be done. An additional paper, Authentic Innovation, (Vernon & Werner) has been accepted for publication in 2009. In the above story, I illustrate how I was able to Manufacture Knowledge for a new discipline for me—mechanical engineering. How was this possible? Perhaps, in no small way, papers in engineering are routinely and methodically produced. In the following discussion, I explore the following questions How are papers written in engineering? What is the outcome of the process? Why are papers written? and For Whom is knowledge is manufactured? Asking these questions about the Manufacture of Knowledge facilitates understanding the motivation for research in engineering theory. It allows the reader insight into all manner of production of papers. This contributes to the referential adequacy of the study, which necessarily encompasses the outcome or purpose of the study (Mulholland & Wallace, 2003).

As I bring the reader closer to a working definition of innovation in graduate student engineering innovation, I come closer to the nature of what engineering researchers do and how they do it. Hence, a brief discussion of how?, what is the outcome?, for whom? and why?
is warranted. In this way, I will show the reader what they may have missed without the
attention to detail here (Mulholland & Wallace, 2003). Some careful readers will not have
missed that I mentioned to Lance I did not think innovation could be taught. It may be
thought provoking to recognise that industry is just as interested in facilitating innovation as
the Commonwealth government. Perhaps more surprising is my incautious proclamation that
it can’t be taught; something I steadfastly clung to as a possibility from my earliest days.

How are papers written in engineering?

The idea for Dock’s paper came to him while he was doing other tasks within the
laboratory. He admitted these tasks prevented him from pursuing the idea. In September,
after some thought of the problem, he began to work through it, numerically as he had done
with the optimisation problem. In this instance, he did not throw away the work sheets. He
worked through 20 handwritten pages of numerical derivations and modeling, consuming a
week of his time in the laboratory. These notes are roughly equivalent to laboratory
notebooks as cited by Knorr-Cetina. Dock effectively derived his algorithm early on but he
needed to ensure it performed well in a number of cases. Dock typed his first technical report
on the Matrix Determinant Lemma on 23 September 2003. This report is as much a ‘progress
to date’ as it is a technical reporting of the phenomenon of interest. It contains an
Introduction, discussion and derivation of the algorithm, and conclusion. Dock produced
weekly progress reports relating to the ‘production’ of the algorithm. As noted previously,
these technical reports are not necessarily for external consumption, but a record of progress
and snapshot of accomplishments to date. After four weeks he had written the code for
MATLAB, debugged it and had the graphical results of the simulation. These results, roughly
equivalent to a science laboratory ‘observations’, are presented in another technical report on
10 October 2003. It is after this that the report is passed to a post-doctoral student for review.
After this review, it is decided that the report can be assembled into a paper for submission to
an international conference in the area of signal processing. Dock then works with an
associate supervisor and the post doc Goran, in formally preparing the work as a paper. The
main supervisor and head of the lab does not comment on the paper until mid October, after
the paper has been revised four times. After the main supervisor sees the paper, it goes
through an additional six iterations. The final version is submitted (uploaded) to the
international conference in October 2003 and accepted for presentation early in January 2004.
Four authors are listed on the paper, though Dock is the first named, indicating he is clearly
the originator of the Matrix Determinant Lemma. Other contributors must always be
recognised, and as Zahir pointed out, the Supervisor must always have his name on the work.

What is the outcome of the process?

The outcome of the above process is a conference paper which conforms to the coda of
the discipline as directed principally by the Institute of Electrical and Electronic Engineers or
IEEE. The IEEE is both a standards body as well as an association of engineers. According
to the website, IEEE, in its 125th year has 375,000 members in 160 countries. “Through its
worldwide network of geographical units, publications, web services, and conferences, IEEE
remains the world’s leading professional association for the advancement of technology.”
(www.ieee.org). Many professional associations have their own publishing standards, and
IEEE is no exception. Dock’s paper was written for the pinnacle publication in the field—
Archives of Engineering, hence all papers in the Archives will conform to the following
template. This ensures uniformity in the review process and ease of readability amongst peers
which in turn drives adherence to quality standards. When papers follow this coda, the
contribution to the stock of knowledge can be easily detected because it should be at the
same place on each publication. Hence, it is a useful exercise to dissect the manner in which the paper is constructed. Dock reported that the paper was exactly put together in the following way: The title Matrix Determinant Lemma is written at the top. The four authors are listed under this, with two each above 2 columns. This is a standard way of presenting information in engineering journals. The left column opens the article with a 40-50 word abstract in italics. Following this is the first numbered section 1. Introduction. In the introduction, background information, as well ‘practical’ application for the algorithm are presented. A forward organiser, outlining the remaining sections of the paper, concludes the section. The next page begins with the second section 2. Matrix determinant lemma. Underneath this is a sub-heading 2.1 The algorithm. Dock then presents the derivation of the algorithm which consumes three full columns, and finally presents the algorithm on third page of the paper in the first column. In an additional section 2.2 Remarks, he presents a brief paragraph clarifying an issue relating to the algorithm. Section 3. Simulation Results presents an explication of figures 1-4 and highlights the four parameters of interest, namely the Minimax, Modified minimax, Maximum likelihood, and Sequential LS algorithm. Section 4 Conclusion is a brief, four sentence paragraph. Following this is a list of nine references, under the heading 5. References. It should be noted that details about the paper, when it was first accepted (March 2005), then revised (June 2006), then finally published (May 2007) are on the first page of the article, along with author affiliations. For The Archives, a lead time of two years to publication is not uncommon.

The engineering contribution of the paper can be ascertained quickly by a review of the Abstract and Section 4—Conclusion. Should a researcher or engineer be chasing an algorithm for improved performance in CDMA systems, they will quickly see if this algorithm holds some promise. Equally, as mentioned before, researchers in academia in the area will easily pick the novelty of the work from those two sections. It is safe to assume that the paper is of sufficient novelty and quality or the reviewers of the paper would not have allowed publication in The Archives.

From the section headers and abstract would a lay person know how Dock manufactured his algorithm? Would they be able to discern the process which I outlined, a priori, in the previous section? Knorr-Cetina suggests that the scientific paper does not contain all the relevant information on how the laboratory results were obtained. In other words, other scientists would find it difficult to replicate the experiment as it is presented in the scientific paper. In engineering, and specifically in this paper, all the relevant algorithms plus notes seem to be included in order than any engineer in the area could replicate the results with the information given. In fact, it is a directive of the laboratory Supervisor that new students read ‘the scriptures’, to borrow a term from Knorr-Cetina, and to replicate the results by working through the equations. Recall Brad actually took a month to read the first paper. Knorr-Cetina’s point is that the scientific paper is a transformation of what occurs in the laboratory, not a summary. She suggests that the work came about due, in the case of protein recovery, to chance, and that, in fact, ‘...the scientists proceeded in reverse order to the sequence found in the paper’. (Knorr-Cetina, 1981, p. 129) Is this different to the engineering paper? According to Dock the paper proceeded linearly, mirroring almost exactly the way he conceived the problem, worked through the algorithm and undertook simulations. I shall explore this in further detail below as I consider the motivation, or the why of Dock’s work.

Why are papers written?

Like Knorr-Cetina, I was very interested in how Dock manufactured his algorithm. Upon asking Dock how he did the algorithm, Dock actually began by telling me why he came up with it—reporting firstly on the motivation for the work which he clearly saw as the genesis
of how one goes about producing knowledge. As noted above, this somewhat contradicts the findings of Knorr-Cetina who suggests that in the laboratory, the genesis of scientific ideas frequently comes from serendipitous moments occasioned by the intersection of a chance occurrence with inquiry in usually another direction.

Dock reports:

Dock: The initial motivation uh ok, first of all it was...firstly I was doing uhm the Leibniz formula where the dimensions of the uh all of the vectors and things are like small...but in the second year when I came to asynchronous CDMA uh, well it requires the uh like stacking of symbols and things and the measures of the vectors are significantly larger than before and if we use the same techniques to compute or to perform uh estimating it takes a long time, so I think ok in practice what should be done in some sort of lower complexity sort of algorithm so I came up with this, ok now, instead of waiting for all sort of observations available and then you estimate the vector, what you do then is say if you have like a smaller subset of calculations you can form some sort of initial estimate, and whenever you have some more observations you can update. That is a sort of practical way to do it, and by doing that you can reduce the complexity significantly. And that is what motivated this work.

The above statement by Dock supports the notion that the engineering approach is unlike the scientific approach in that the intention of the research is a purposeful and linear exploration of an idea, and that the production of the paper does in fact mirror this linear model. That is not to say that the engineer is not opportunistic. Knorr-Cetina notes ‘...to a great degree, scientists select areas of work which have not been covered by previous research; thus, their results are almost guaranteed to pass as new.’ (Knorr-Cetina, 1981, p. 13) Dock certainly selected such an area as he frankly reported:

Dock: With this paper I did more ...you have to compare the previous work in this area where in the book by Steven Kay he initially derives in detail the algorithm for the case where the noise is Gaussian, but no-one seemed to derive the algorithm for the case where the noise is non-Gaussian because first of all it is non-linear and secondly it is mathematically complicated. So I try to do it.

So in this sense, the choice of the research area is similar to science, so both engineer and scientist have educated guesses as to where to look, what to ignore and what counts as a solution (Knorr-Cetina, 1981, p. 12) As Knorr-Cetina notes, this is the true source of innovative results. Research in education, science and mathematics all commence with the same rubric—the literature review + intersubjective dwelling in the subject = a honed down topic of research which no-one else has pursued. We do not seek to duplicate or repeat the same results of previous researchers, but rather to carve our own area of research, novel for whatever reasons. To do otherwise would negate the conceptual basis of reflective inquiry—namely that we can as researchers draw attention to new ways of understanding, new learning, new knowing. This is why written work which suffices the rigours of the academy, be it the engineering or education academy, must be, shall be innovative.
For who is knowledge manufactured?

Dock produced the algorithm based upon his educated guesses, knowledge of what to ignore and what counts as a solution. He successfully proved to his supervisor that his work is novel enough for consideration for an international paper. Together, they negotiated the final production of the paper. Then what? What will happen to the Matrix Determinant Lemma after that? Dock hopes that due to the novel nature, his algorithm will be accepted, but more importantly, used by the international community. In this, he is exactly like the scientist Knorr-Cetina reports: “A scientific product which cannot inscribe itself, or impose itself, as a resource to be converted into the ongoing enterprises of other social agents will be neglected and ignored.” (Knorr-Cetina, 1981, p. 129) To have one’s work ignored virtually nullifies the work of engineers who pride themselves on their purposeful exploration and utility of the productions of their work. Moreover, Dock reported ‘it is a good thing to have in the PhD’. Dock has become skilled in coming to know the area of signal processing in depth. He reported (in 2003):

…the most rewarding thing is that I can read papers very easily…[they are] easy to understand and I can decide what is important…and which is important for my work…yeah, yeah, I think to have that kind of good understanding about a field is the most rewarding. I mean…in my opinion…with the graduation [in three years]…you cannot do a significant thing…the PhD is a time where you learn to know that thing…and you study it in depth…you prove to people that you can do something and you actually get to have vision. Some people might want to make something…build…but in the signal processing area it is something that expand your knowledge, you answer the fundamental questions…you understand the matrix…for a PhD you don’t make a TV…and you don’t make a radio cassette, but you know the principle of how it works, given [that] you know how to tackle the problems.

Dock’s first findings on the Matrix Determinant Lemma were presented at an international conference in May 2004. The concept formed the basis for a journal submission to the Archives. Was Dock’s Matrix Determinant Lemma for innovation or was it for fun? Or was it to fulfill his promise to his supervisor? For whom did Dock produce the work? As noted above, it appeared in The Archives of Engineering in May 2007.

Phenomenon 5 The MANUFACTURE OF KNOWLEDGE Discussion

The story I used at the beginning of this section to illustrate the phenomenon of MANUFACTURE OF KNOWLEDGE is a story of mine. I also have discussed how a real engineer constructed his paper. Our construction processes were similar in that they were both borne from a kernel of serendipity, Dock taking an educated guess as to where he might find something novel to manufacture, and I was directed where to look! Have I successfully captured the essence of innovation in either? Using Dock’s model to create my own work, I believe I have successfully understood and transferred the model of how one constructs knowledge, because I successfully reverse engineered or deconstructed his method and applied it to my mechanical engineering paper—writing my own ‘scriptures’. Is this innovation or just good acting? Was Dock’s paper novel, or did Dock also become a better actor? Dock produced six papers from the time he came to the research group in March 2001 to graduation in 2005. Two of these papers were for international conferences and four were national, local or postgraduate conferences for research centres with which Dock was
affiliated. I have produced a number of papers, articles and chapters in education. In keeping with the cross disciplinary nature of this thesis, I have also published in engineering.

As humans, we desire to be creative, to learn to understand and be understood. Some people, like engineers, are driven by the need to solve problems in innovative ways, and apply these to everyday life. Others, like me, are driven by quality standards in higher education and industry. Both Dock and I seek to make an impact, no matter how small. We pursue Mmoatia, truculent and fleeting innovation. For us, the pursuit involves processing information and manufacturing knowledge: papers, articles, conference presentations. This is an essentially linear, academic model. But what occurs in practice? For two years, I have worked in industry, and innovative industry at that. I am lucky enough now to say that I watched innovation happen, and now I have close to full membership in this community. I am a "confidant of the company.” In industry, innovation normally happens after trial and error, so it is easy to spot. Documentation is rare, not only due to commercial reasons, but also because the engineers and practitioners are launched into the next profitable project as soon as, or before, a project is completed. What did I learn from three years chasing innovation and two years being a part of it? The answer to this question is the subject of the final section, V Findings.

Analysis and model proposition

This section will summarise and analyse the five phenomena: APPRENTICE LEARNING, SOLVING TO SOLVE, CARE & CONCERN, VOLUNTARY INATTENTION (play), and MANUFACTURE OF KNOWLEDGE. It will map the phenomena to the story and to the archetype. It will suggest a model arising from the data, and how the phenomena map to the stories and the archetypes in the following way:

<table>
<thead>
<tr>
<th>Phenomena</th>
<th>Story (#)</th>
<th>Archetype</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 APPRENTICE LEARNING</td>
<td>The Supervisor (2)</td>
<td>Osebo</td>
</tr>
<tr>
<td>2 SOLVING TO SOLVE</td>
<td>Dock (3)</td>
<td>Mmboro</td>
</tr>
<tr>
<td>3 CARE &amp; CONCERN</td>
<td>Zahir, Brad (4, 5)</td>
<td>Mmboro</td>
</tr>
<tr>
<td>4 VOLUNTARY INATTENTION</td>
<td>Safwan (6)</td>
<td>Mmboro</td>
</tr>
<tr>
<td>5 MANUFACTURE OF KNOWLEDGE</td>
<td>Tanya (7)</td>
<td>Mmoatia</td>
</tr>
</tbody>
</table>

Table 1 Phenomena -Story-Archetype

Commencing with APPRENTICE LEARNING, one can organise the phenomena in such a way that gives a notion of the circular and iterative process upon which pivot the flow of ideas and students. Graphically if I plot the phenomena as five nodes of a pentagram, I can see both system and process emerging. And within the system, I suggest that there are three ecologies. If I link APPRENTICE LEARNING, SOLVING TO SOLVE and MANUFACTURE OF KNOWLEDGE into an Ecology I envisage as a Network Ecology, where the Supervisor is dominant, and needs to be in order to represent and replicate the work of the lab in an ongoing basis. The Supervisor produces the network Ecology as he and his students seek for their work to be accepted by the academy. For the network to be effective in replicating itself, it indeed requires: APPRENTICE LEARNING, SOLVING TO SOLVE and, of course, the MANUFACTURE OF KNOWLEDGE. It has a quality management system which allows for peer learning and exchange of ideas, solitary problem solving and output of papers— but with the crucial link of the Supervisor to moderate and ensure quality for the global community of researchers, and return the mores of the academy to the students. For another, Ecology, I propose utilising the following three axes: SOLVING TO SOLVE, CARE AND CONCERN, and VOLUNTARY INATTENTION. If these are utilised, the students are dominant. This Ecology is a social Ecology, where the students have a behavioral space or
house where they can stage the dramas, interactions and emotional inter-play which form the ordinary-ness of the daily life in the laboratory. The social Ecology is interdependent upon the network Ecology and vice versa. Finally, if I prepare another Ecology with phenomena of *SOLVING TO SOLVE, VOLUNTARY INATTENTION* and *MANUFACTURE OF KNOWLEDGE*, I now postulate a knowledge Ecology which essentially connects or resolves the divergent world of the Supervisor, bereft of social and the students, oblivious in the immediate sense to the demands of the network, with a knowledge Ecology that is individual and social yet connected to the needs of the network in terms of communicating one’s ideas through the *MANUFACTURE OF KNOWLEDGE*.

The model might look something like this:

![Figure 4 Graduate engineer knowledge acquisition model (GE-KAM)](image)

The model suggests a synthesis of the discussion of observed phenomena from the laboratory, and the notion of three Ecologies. To further hypothesise, the model suggests how graduate-student research engineering student knowledge acquisition is *driven* by processes and relational interactions of the students as they transition through the Ecologies. No singular Ecology can itself drive knowledge acquisition, because the impetus is driven by the others in an ongoing and evolutionary cycle. Like a treasure hunt, the student can move in and out of each Ecology, at any time in any order, but without all three, the student will have failed. Like Ananse the spider man, the student must make the journey, and must dwell in all three before he can be deemed ready—for the gift of story, for the whatever goals drive attaining a PhD.
Anecdotally, it seems a common complaint of graduate students that they are given trivial or even dismissive feedback. They complain of lonely, predatory or even hostile treatment from supervisors. In reality, if the Graduate Engineering Knowledge Acquisition Model (GE-KAM) is considered, the Supervisor is but one third of the equation—causing effect in only one of the ecologies, the other are totally within the locus of control of the student. What this means for the research higher degree student is profound. It not only demonstrates that the long lamented uneven power relationships, advantage supervisor, are bunk, it puts the onus for knowledge acquisition squarely on the shoulders of the student to make of their degree what they will. Finally, the one model actually gives both supervisor and students a kind of position description of what each should be doing in terms of mentorship, peer support and reciprocity.

Does determining how a graduate student in engineering attains knowledge assist in learning how they innovate? Not quite, but it brings me much closer. There is one further question which must be addressed. In the final lead-up to addressing How does a graduate engineering student innovate? I ask: What is the nature (or purpose) of the PhD? This next section will be a brief segue to the V Findings section which will address the thesis question.

In the above section, I discuss the how, why and for whom knowledge is manufactured. If the reader would be able, according to information included in this section, to provide the outline of an engineering paper, then this section has been successful, not only in demonstrating exactly how papers are manufactured, but also how one can make initial forays into other disciplines—how they can ‘border cross’ into allied field. If a reader can envision this process, then this section has been convincing, and has a high degree of SHARING. The final three sections of the thesis: IV Linkages, V Findings and VI Epilogue shall adhere to the SERVICE criterion. This criterion is concerned with the outcome or purpose of the study.
IV Linkages
4. So small, so small, so small

Ananse spun a web round Osebo,
Mmboro, and Mmoatia.
Then he spun a web to the sky.
He pulled up his captives
behind him, and set them down
at the feet of the Sky God.

“O Nyame,” said Ananse, bowing low,
“here is the price you ask for your stories:
Osebo the leopard-of-the-terrible-
teeth, Mmboro the hornets-
who-sting-like-fire, and Mmoatia
the fairy-whom-men-never-see.”

Nyame the Sky God called together all
the nobles of his court and
addressed them in loud voice:
“Little Ananse, the spider man,
has paid me the price I ask for my
stories. Sing his praise. I command you.”
Linkages Discussion

In the previous section, I suggested a Graduate Engineering Knowledge Acquisition Model (GE-KAM). I hypothesise that the phenomena form a constellation of three Ecologies which interplay to facilitate the uptake and moreso, transmission of knowledge. I have called the three ecologies the Network, the Social and the Knowledge Ecologies. Upon my in-depth investigation in previous sections, it is now easier to see how the ecologies come about based upon five key phenomena which are iterative and interlink with one another. But why? Why do the students or the Supervisor bother with such highly theoretical studies? Why are they chasing $\hat{\Theta} = \text{Theta-hat}$? To ask why? questions such as these drives at the heart, the impetus and intent of gaining a thesis. Put another way, one might ask: What is the nature (or purpose) of the PhD? This is the second thesis question which, once answered, will assist in unpacking the over-arching thesis question: How does the graduate engineer innovate? to be addressed in section V, Finding. While What is the nature (or purpose) of the PhD? seems a fundamental question, it is, in fact, an extraordinarily relevant question today, as Australia experiences a general decline in the number of Australian engineering and science undergraduates going on to pursue research degrees.

In dissecting the question What is the nature and purpose of a PhD?, one must strike at the heart of motivation. To study motivation, I asked three questions in my interviews with the students. These questions now prove valuable—what is the most rewarding experience?, what do the students think is the most valuable skill learned? and what is their definition of engineering? Through my discussion below, I will then connect these questions to the three ecologies in the Graduate Engineering Knowledge Acquisition Model. The discussion of these three questions, which hopes to address the motivational structure, will, in turn, help answer, at least from the point of view of the students and supervisor, what is the nature and purpose of PhD? With this linkage in place, I will be in better position to suggest a fully informed definition of innovation in graduate engineering students.

Student—Most rewarding experience (Network Ecology)

If innovation and utility reside together, but the students don’t dwell here because of their pursuit of more fundamental research, what continues to propel the student toward completion, how do they derive fulfillment of their aspirations, particularly over many years? In short, what do they find rewarding? When I ask the students the most rewarding experience of their work, I see that it generally centres upon a common theme of getting work accepted, in the form of the thesis or papers, or when their algorithms work. In the following section I explore the most rewarding experience and how this maps directly to the Network Ecology as proposed in the GE-KAM.

What they say  Marvan was somewhat unique in the lab for three important reasons: he came to the PhD after working in the railroad industry, he had a different supervisor than most of the other students in the study, and he implemented his algorithm on a real modulator. He spent most of his time with Safwan, and in fact, Safwan stayed with him during some medical complications. He responded to my question of what is his most rewarding experience, thus: “Whatever I have established in theory I can see it practically. It is more satisfying to see that I can apply my theoretical analysis right and do practical implementation.” He goes on to say that others work at a more theoretical level and he actually implemented his solution with a modulator: “Theoretically you can do the wrong theory and write the wrong program [ie
simulation] and still it will work on paper. But you won’t know. Also, I like the practical side.” Marvan comments on the utility and practicality of his research. What do the other laboratory students find rewarding in the research they undertake? In 2004, Dock reported that the most rewarding thing was the ability to, think, to think and to write more professionally. For Brad, too, the writing, or codification of his ideas, in his thesis was the most rewarding thing:

Brad: Well, I did have a couple of times during the three and a half years, four and a half years that would almost seem like an epiphany, a technical epiphany. And when you see something work, or when you hear that your paper has been accepted, then it is a rush. But looking back on it, it is insignificant compared to actually completing the thesis, cause the thesis is a solid three-six months of work, uhm, the paper is a couple of months work. So it is great to get those technical moments of epiphany, but it is ...the single greatest satisfaction without a doubt is finishing.

The most rewarding thing for Brad is the actual completion of the thesis. Goran, the other post-doc, agreed with this. As demonstrated by Mark, who was nearly finished at the time, having one’s work accepted is the most rewarding.

Mark: Uhm, [pause] it is always rewarding to get a paper accepted and to have some kind of feedback and confirmation that your ideas that you are working on are relevant or worthwhile to other people, of interest to other people, so mainly the feedback that comes from publications, because that is like a milestone, that is how you say you have completed something or you...it is not really anything until you write it down, if you know what I mean.

Mark actually summarises it efficiently in the highlighted section above. What occurs with writing is a codification of ideas, and while Mark admits elsewhere that the contributions may be epsilon contributions, he knows that once they have been written down, reviewed and accepted by peers they can go on to be added to the stock of knowledge. Ideas as written or codified are not commonly thought of as innovation in themselves. However, in academia, ideas which are not articulated are nothing. In a real way, Mark’s statement epitomises the concept of the Manufacture of Knowledge. Equally, the Supervisor also believes that the most rewarding thing in supervision is seeing the ideas of the student accepted to ever widening of group or academe:

The Supervisor: The most rewarding aspect is to see some of my former PhD students being, holding prestigious awards uh, holding prestigious positions, being internationally known. My colleagues tell me how, when they meet me at conferences how is this guy doing, your former PhD student and some say, you know, I saw a paper by your former PhD students in another journal you know, he is doing well.

I believe the Supervisor takes pride in the fact that his students are doing well. If nothing else, this illustrates that when Student and Supervisor engage in buying into the academic model they align themselves to perpetuate that model. Recall that the Network Ecology is bound by Apprentice Learning, Solving to Solve and the Manufacture of Knowledge. The Supervisor is the gatekeeper of the network Ecology which is then connected to the outside world via professional linkages such as the peer review system for publication and grants, the examination of theses, even linkages with industry. Without the Supervisor, the students may have little success in getting work accepted by the academy. It is his presence, his membership of numerous editorial and conference technical committees that provide a segue
for the students to become published, to be introduced to the network of engineers and scientists working on the next generation technologies for defense, consumer applications and industry. He provides a venue for the students to get a reputation as thorough acolytes or apprentices of the Master. To get connected with the academic publishing network or industry network is as much about “who's lab you came from” as it is about the quality of one’s work. Hence, the Network Ecology produced by an intersection of the three nodes of APPRENTICE LEARNING, SOLVING TO SOLVE and MANUFACTURE OF KNOWLEDGE, provides a connection to the outside world via the network as established by the Supervisor.

As long as the student upholds some simple rules, such as writing and publishing to the coda, completion of milestones and writing the thesis, the Supervisor in general will respond in the same way each time. He will link the student to the international community of Signal Processors. In the years I spent with the lab, there were several times students didn’t comply with the basic expectations and the result was that the student was informed of the transgression. If it occurred again, and it did with one student, that student was eventually not supported—basically by non-sponsorship into the Network. While this may sound harsh, in reality, the Supervisor must uphold quality standards in the lab and can ill afford a rogue who might enter the academy and behave badly. This would not bode well in terms of quality and perpetuation of the reputation of lab. If the rules are so commonly held and easily understood, why would a student knowingly transgress them? The answer may lie in the fact that the student failed to align himself, define himself along the same terms as the Supervisor.

For this next question, I look at how the student defines himself. In this, I draw the reader’s attention to the fact that when I asked, each and every student was careful to indicate that engineering is applied, that it is applicable to real world problems. In getting the glimpse of how they define themselves, I find their connection with applicability to real world problems helps separate them from pure scientists. In this, engineers are directly linked to society, for without that continual interplay with “real world problems” in society, they might have chosen a different discipline. The Social Ecology, bounded by SOLVING TO SOLVE, CARE & CONCERN and VOLUNTARY INATTENTION facilitates the growth of the student toward a social trajectory. In the comfort of peers they practice peer to peer assistance, mucking around and everyday relationship building. In this Social Ecology, they hone their skills for lives after the PhD.

**Defining us...what is engineering? (Social Ecology)**

One of the earliest questions I had identified I wanted to ask the students is how they defined themselves, what they actually thought engineering was. One reason I wanted to do this is because early on, Goran one of the students I later interviewed as a post-doc, sent me a lengthy four page e-mail concerning being a PhD student and some differences between engineering and science. I have retained this e-mail, in spirit and in reality for seven years now. Part of it is replicated below:

> Well, I remember this intro to civil engineering in the first semester of my degree, back at good old Uni. The definition of engineering was essentially: Engineering is applied mathematics and physics, but which takes into account previous experience and common sense. The context, being civil eng included examples such as
> 1) the pyramids - very mathematical in shape and design, but because of uncertainties in the materials,
took several goes before they found what worked and what didn’t (i.e. if the sides were too steep – it would collapse)

2) churches built pre-1600 (pre-Newton) which were based on what worked in the past. Then you get to Newton’s era when the entire structure can be analysed and you can make sure the supports are enough to keep things standing… even so there are still things you can’t analyse (because of expense or time, or sheer complexity) and you just have to try them and hope you’ve got it right.

So I guess what I’m saying is that some areas of engineering are so well founded and thoroughly understood in theory, and proven in practice that they are taught and practiced scientifically, i.e. here’s the method and it works – step 1 dahdahdahdah, step 2 blahblahblah, While we’re talking about theory and practical experience, the general structure of discovery is: Discoveries in mathematics are applied in fundamental physics and these are both applied in engineering.

For example, special relativity used high school mathematics, Newton would have followed the maths easily (he ‘discovered’ the mathematics that was used). General relativity also used mathematics developed by a guy hundreds of years ago – but was thought to have no practical application. These theories have been used recently – for instance – I’m pretty sure special relativity is used in the global positioning system. [personal email correspondence dated 30 June 2003]

I have retained Goran’s e-mail in paper copy to today because I find it simply one of the most harmonic ways of defining engineering. In fact, it is so harmonic, simple and powerful that Goran remembered it and was able to relay it to me. Note Goran’s ability to understand engineering in terms of, not in juxtaposition to, physics and maths. Goran has a very casual but informed style. The reader hears from Mark, Zahir, Dock, Safwan, Brad, Tom in the passages below. Again, the reader should be careful to watch where students insist engineering must be applicable to society.

Mark 2004

Mark: Solving real world problems. Applying mathematical or scientific knowledge to satisfy the needs of society.

Zahir 2004

Zahir: Engineering. Yeah. Well that is basically being able to solve a problem or to fulfill a requirement uh a requirement from some say client or customer in a given situation in the most optimal way that is taking into account the constraints of cost and time. And because we are engineers, we do it essentially technically, but not necessarily, not always.
Dock 2004

Dock: Well engineering practice from my understanding is that it is to apply the knowledge of science. Turn science to something that can help people [and the]...motivation comes from practical problems.

Brad (2004)

Brad: Uhm the process of converting physical principles and theories uhm into uhm useful applications and products that have uhm a purpose. It is not knowledge for knowledge sake, which is more pure physical sciences, but uhm an application of that knowledge towards uhm a goal that would be of help to someone. Uhm, that can still be fairly abstract, but I believe that engineering is all about building things, certainly not all about physically building things by any means, uh I think it is the link or conversion of physical principles or physical truths to uhm a physical reality or a physical application.

Tom (2004)

Tom: My idea of what engineering is, I don’t know if this answers your question, engineering is applying physics and mathematics to solving real world problems. So the practice of engineering, well, for most engineers when they do engineering, it is just remember some things from first or second year, very basic stuff, and just applying to a very simple problem. That is what most engineers do in the workplace. Uhm, research engineering is a bit harder, you are using more advanced tools that are maybe changing and being developed over time so in order to use those tools to the best of your ability [mumbles]...you know, it is just applying a set of tools or understanding to solve some problem.

Safwan (2005)

Safwan: Uh, engineering...uh...it is not mathematics, it is not like, uh simulations. For me it is a realistic thing, you have to look at it from this point of view...A real problem, if you can look at in real life from certain direction and you can pick it up, then you can go back to the simulation. ...That is engineering for me. It is a real thing. You have to feel the problem...if you look at it, you can feel exactly like, what is happening, like if it is a bridge, you have to feel ok, the bridge, and you have to stand and feel the weight, before putting the structure. You try to analyse all of them...all of the things mathematically.

I note Mark’s very simple words “Solving real world problems. Applying mathematical or scientific knowledge to satisfy the needs of society.” Others are much more verbose, but all of the students essentially say the same—it should use math and science, but it must be connected to some external driver—society, industry, client, for utility or purpose, for the real world. It is not about pure knowledge for knowledge sake. I sense Mark is telling me something there, and I wonder if has to do with a possible paradox about undertaking a three to four year research project in statistical signal processing where the simulations and theory tend to the more theoretical end of the spectrum rather than the more practical. The engineers occasionally note this irony in some of their discussions and stories, but Mark, again, puts it clearly:

Mark: Uhm, well in our kind of research it seems to be most of the time, in the theoretical side, kind of small, what would you say, epsilon contributions. So you take what someone else has done and you extend it by a small amount, which is
somehow significant enough for other people to say, to be able to then say, ok, that is something interesting and I can extend it another small amount. **But it terms of big, sort of innovation, that comes, is driven by--industry.** You can think of any theoretical topic you want, but until someone from industry says “you know we have this problem and we don’t know how to solve it with our current methods”...then you don’t see like a huge focus and a lot of people working on that topic and trying to find where the theory fits in this area and try to come up with new ideas, new algorithms. It seems to be fairly driven by some kind of industry. I mean, that is engineering. **It is not pure mathematics.**

Can I infer that Mark believes big innovation and mathematics are mutually exclusive? If he does, this would hardly be a surprise to me because the words the students use to describe engineering are perhaps synonymous with innovation: **solving, applying knowledge, real-world and society.** Mark makes an important point in the above paragraph. He realises that questions from industry **drive** innovation in engineering. This is evidence of mature thinking. I believe all of the students are able, as contemplative adults, to realise their ultimate connection with industry or society so the direct linkage between ‘defining us’ and the phenomena of **SOLVING TO SOLVE, CARE AND CONCERN and VOLUNTARY INATTENTION** can now be drawn unequivocally. The Social Ecology which is the nexus of the three phenomena serves as a crucial connection to the future of the student—it provides an impetus, it drives them in their engineering endeavours. They seem to crave this connection and perhaps as a way of mastering the situation in which they have less control, they are able to ‘act out’ and prepare for an external, outside world in the relative comfort among their peers.

“It is only an epsilon contribution” Mark says of his work in the above quote. He goes on to say that it is somehow significant enough for others to take and build on. So, what do the students believe is the most important thing they will take away from their PhD candidature? What will they learn? Why would they remain in the program if they did not want something to take away? The final question addresses this exactly—what is the perceived benefit of the PhD program?

**What is most valuable/fundamental skill learned? (Knowledge Ecology)**

In the previous sections, I looked at the perception of the most rewarding aspect of student work and how they defined themselves. In this section, I see yet another driver of what getting a PhD might mean to the students. When I asked students to quantify the most important skill they will bring to their chosen area, I get at the heart of what is the purpose, for the student, of undertaking the PhD. I like Marvan’s words that he uses when I ask him about his most valuable skill: ‘Only one thing I will bring--the systematic attacking the problem!’ Attack! Now that is the kind of excitement that is rather unusual amongst the engineers. A more moderate and commonly used word is the word ‘approach’, as Tom discusses below:

**Tom:** Hopefully sort of ...the thoroughness in my approach...uhm...yeah, just being careful at each step of the process and uhm...when solving a difficult problem you have to break it up into small sub problems and if each of those sub-problems is solved to an acceptable level where you go ...ok, that is done...

Safwan also agrees that is it an approach, noting especially that it is looking at problems from differing view points. Zahir likens it to modeling in design work: “.... is the way of approaching problems, the way of modeling different situations in order to solve a given problem, so it is basically a way of design. This is basically the way an engineer...it is a lot more important than a specific skill or uh specialty....” While Safwan, Zahir, Tom and most of the
others agree that it is an approach, Dock and Mark have an ever so slightly different notion. Mark notes: “Knowing how to teach myself what I don’t know”. This sense of adaptability is equally true with Dock: “Skills...uh...the...after the PhD what I can do is the ability to quickly learn to quickly adapt to the work environment and I can easily read the journal articles…”

From my point of view, certainly Mark and Dock suggest a crucial outcome of achieving a PhD. This is the ability to quickly learn and/or teach oneself what one doesn’t know—where I have noted as a crucial “deliverable” for students who choose to go on to industry. I believe it is something I took away from my time as a researcher also. It is rare for a student to do professionally exactly what s/he did as their thesis project. It may occur in a post-doc or academia, but even then, the academic will be expected to expand the work of the narrower thesis. The ability to teach oneself what one doesn’t know is in fact an incredibly powerful tool that will pay multi-fold as the researcher moves into employment past the PhD. As Dock notes “…to quickly learn to quickly adapt to the work environment…” This is particularly important in industry where many projects have a short life span and where the project manager or engineer must be able to handle many of them and deliver on time and on budget, and jump to another before the first is fully complete. The ability to discern what is trivial detail and what is crucial information for the life of the project is also of key value. This is where learning a model or an approach comes into play. If one does learn the “systematic attacking of the problem” effectively, then one knows how to frame, ask and answer relevant questions, and subsequently drive projects toward answering the questions. If this becomes second nature to the student, then they are likely to be able to model any kind of problem in mostly any related discipline. The student perception of their most valuable skill links directly to the Knowledge Ecology. Recall that the phenomena evidenced in the knowledge ecologies are MANUFACTURE OF KNOWLEDGE, SOLVING TO SOLVE and VOLUNTARY INATTENTION.

While the phenomena of SOLVING TO SOLVE links to the student ability to teach oneself what one doesn’t know, and the MANUFACTURE OF KNOWLEDGE is somewhat self evident in that the student must learn an approach to creating knowledge in a systematic way, the importance of VOLUNTARY INATTENTION is less obvious. Why would VOLUNTARY INATTENTION be important as the student went into industry? The answer to this lies in the fact that students who are able to become involved and communicate with colleagues in a playful way will become valued team members who are able to laugh at themselves and trivial mistakes while undergoing the tremendous stress that can be involved in bringing projects to fruition in industry. An element of playfulness and the ability to not take oneself so seriously will make transitioning from a world where teamwork was minimal to a world where teamwork—collaboration, communication and compromise are essential!

Segue The question which section IV Linkages hoped to address was “What is the nature and purpose of the PhD.” I explored this question by breaking it down into three separate questions which I addressed via information from the students and the Supervisor. Through answering each of the following questions in a brief way: what is the most rewarding experience? Define us...what is engineering? And what will be your most valuable contribution?, I have shown how the students conceptualise what engineers are and how they will contribute to their chosen fields. I have also linked the engineers “raison d’etre” to my Graduate Engineering Knowledge Acquisition Model, thereby answering both the how and why questions about knowledge acquisition. In the penultimate section of this thesis entitled V Findings, I will discuss how the students and supervisors deal with innovation in their work, I will define innovation in research and discuss the thesis title: Sacred Knowledge. I conclude by giving a personal account of how innovation learning can be facilitated via an
intersubjective method. An intersubjective method, is one which relies on ‘ethnographic empathy’ as defined by Jackson:

Ethnographic empathy, on the other hand, is grounded in engagement. It begins with the social skills without which an ethnographer simply cannot endure life in the field, and is augmented by praktognosis, born of cooperating in quotidian work with others—farming, fencing, threshing, parleying. It is a mode of embodied, intersubjectively negotiated understanding that comes of coexistence and coordination in common tasks; it is not a form of knowledge consolidated in precepts and enshrined in dogma…It must entail a psychophysical going beyond one-self in shared practical activity. (Jackson, 1998, p. 98)

How do the graduate students innovate? In order to be truly innovative, must the students, as Jackson suggests, become grounded in engagement? Should the students possess some sort of ethnographic empathy? I argue in the final section that the activity in which they are engaged—where they co-operate and co-exist in practical activity produces innovation which is relevant to a research degree. Being innovative in a commercial sense will occur when and if there is an industry driver, as Mark has said. However, because there is no direct industry driver does not mean the research is less innovative, as I discuss in the final chapter—V Findings.

In the IV Linkages section above, I have attempted to show to the reader the process by which the students move through the Ecologies of Network, Social and Knowledge attaining skills in order to become successful graduate engineers and fulfill their goals. I discussed the Graduate Engineering Knowledge Acquisition Model and relate three questions to the Ecologies: What is the most rewarding experience? What is the most valuable skill gleaned from the PhD? and finally, How do you define engineering? These are all “coming to be” questions. In the section prior to this one, III Analysis, I unpacked how the graduate students did what they did. I painted portraits of the Supervisor, the students and myself, and gave a recipe of how together we mechanically manufacture knowledge. But why? Why are the students willing to spend 3-5 years of their lives in research and writing? What are the motivators of the mechanics of what we do? Offering the reader the motivational, the emotive reasons for research and writing, contributes to the SERVICE criterion. In this way, the reader can thus deduce, as I have, the definition of innovation. Without discussing motivation, the reader might be left wondering how I arrived at my conclusions. In this way, I have given the reader information to which they might not have had access. If the reader now feels they have a good idea as to what motivates students to do what they do, then I have been successful in term of SERVICE.
V Findings
5. If it be sweet

“From this day and going
on forever,” proclaimed the Sky God,
“my stories belong to Ananse and shall be called ‘Spider Stories.’”

“Eeeeee, Eeeeee, Eeeeee,”
shouted all the assembled nobles.

So Ananse took the golden box of
stories back to earth, to the people of his
village. And when he opened the box
all the stories scattered to the
corners of the world, including this one.
Findings Discussion

In the previous two sections III Analysis and IV Linkages I revealed a Graduate Engineer Knowledge Acquisition (GE-KAM) model based upon five key phenomena which link to three interdependent ecologies. I have derived this model from the data, but data acquisition was always driven by ‘reason for being questions’ that I asked a priori at the commencement of the PhD. To return to them they are: 1. How is knowledge acquisition driven in a graduate engineering laboratory? 2. What is the nature (or purpose) of the PhD? In pursuing these two questions I attempt to understand the more fundamental question of 3. how does the graduate student in engineering innovate?

The fifth and final section V Findings of the thesis has two themes, one theme is to explicitly address “how does the graduate student in engineering innovate”? The second theme considers the title of the thesis: Sacred knowledge.

How does the graduate engineering student innovate?

What do students think about innovation? Do they think they are innovative? In this first theme of the final section I deal with a multi-representational view of innovation. Because I worked with adult learners, I can query them about what they think innovation is and whether they are innovative. So, perhaps atypically for a penultimate thesis section, I shall present the points of view of the students. Then, drawing upon all of the data is the culmination of the thesis—a definition of graduate student engineering innovation. After this, I suggest some capabilities which may foster innovation in student communities of practices. The capabilities are taken from and map directly to the three ecologies: Network, Social, and Knowledge.

The second theme deals with the title of the thesis: Sacred knowledge. Is the title an oxymoron? What is the meaning of Sacred knowledge for my context? I go on to discuss my personal journey in relation to innovation and suggest a possible intersubjective research methodology which is based upon the intersubjective method proposed by Michael Jackson in Minima ethnographica. I conclude the section by suggesting that to be truly innovative one must engage in intersubjective learning.

Theme One How does the graduate student in engineering innovate? In terms of output, innovation in research contrasts sharply with classical innovation which traditionally incorporates commercial implementation of ideas. Conceptually, however, innovation in research and classic innovation have the same root—the acceptance of one’s expressed ideas by increasingly larger networks. Does a chasm exist between the acceptance of ideas by the academy or one’s peers and the mass commercial realisation of those ideas? A case in point is the plasma screen invented at the University of Illinois Urbana–Champaign in the early 1960’s by Donald Blitzer, Gene Slottow and Robert Wilson. Though my classmates and I used them in the PLATO lab in the 1980’s, the mass commercialisation of this idea occurred within the last decade, after further refinements by Fujitsu and Panasonic. The Supervisor in the thesis in fact notes this difference in classical innovation and innovation by the students:

This is innovation that you come up with something new, totally new to solve a problem no one has attempted and then it finds solution or application in various disciplines. If I define innovation as such, ok, I haven’t seen any of my students being innovative. [small laugh]. But that is too strict, you cannot
allow that because if you use this definition for innovation, I mean there are thousands of researchers in our field who are basically useless, not innovators. They are not innovating anything. So we have to compromise a little bit...

It is heartening that a compromise was considered and the Supervisor wisely mitigated a strict interpretation of innovation for his students and other researchers. The position of the Supervisor is to facilitate the creation of work that is a novel contribution to the stock of knowledge, and of course to instill confidence in the students who create it. I asked Brad, the post-doc “So do you feel your PhD was innovative?”

**Brad:** Yes. Uhm. I think everyone’s PhD is innovative...it is something standard, I know most PhD students feel this way, and no-one had done exactly what I had done before, so...if others think it is important, that is another matter, but I don’t think there is much doubt that...I haven’t seen anything so far, in the four years after that to suggest that someone else has done it. So yeah.

Safwan comments on innovation:

**Safwan:** It depends on the person. You have to think about how to update things, and stuff like this. You have to keep it parallel with these things, you don’t have to do the same thing...you have to be with the new stuff, as well. This creates innovation.

Yasir comments:

**Yasir:** Uh, innovation happens when you let’s say, for my case, I read a paper and then you find out uh the research activities or weakness of a certain class? And you explore it how to manage this application to overcome the weakness, and then that is the innovation comes...so you can do the same modification for example, and also you bring a new technique or something...that is innovation.

Tom comments:

**Tom:** Uhm...probably what I think is...you never get truly novel ideas...I mean one thing is always uhmm simulated from another thing which may be similar...probably seeing sort of the uh...the links between things...for example, one person will come up with an idea based on this and then you might see that idea, and with your current problem you go...that is sort of similar, but...the idea you are looking at is sort of evolved from previous ideas that were similar as well. So it is like an evolution ...you go now...that is sort of similar to that...now if I can just change my perspective abit then I’ll be able to apply it to this...and so sort of...it is an evolution of ideas...and you see one thing that makes it slightly different and then the original idea either changes slightly or becomes useful for something else...but yeah, you have to be a genius or something in order to come up with something truly revolutionary and a lot of people come up with great innovations and we’re not all geniuses. So...it is just simple progression and the different take on the picture.

Brad echoes the feelings of others who I have talked to informally since their graduation. In fact, if the condition of ‘novel contribution to the stock of knowledge’ was not fulfilled, the theses of all the students of the lab would not have passed. In considering the previous section IV Linkages where I described the primary nature and purpose of the PhD, combined
with an understanding of the views of students and supervisor, I can now deduce a general definition of innovation, as I attempt in the section below.

**Definition of innovation**

Innovation can be illusive, even for those working directly within traditionally innovative fields. Such is true of the students working with fundamental/basic mathematical concepts which ultimately may be implemented years later on a chip. Researchers ask “Does this improve efficiency?” On the chipset, a nanosecond improvement in computation might improve computation time. Will the savings in computation time prove commercially viable? Bigger questions arise: in manufacturing, does a small change in fabrication make something innovative? Is one algorithm an innovation? Does one modification to a traditional tool mean innovation? I cannot be sure, but I have substantial evidence from the numerous interviews presented herein that the researchers themselves believe “...it is nothing if it isn’t written down.” The following definition is thus derived:

**Innovation in graduate engineering student research effloresces in the acceptance of ideas by discipline peers and potentially society.**

What the definition means is that in order for research to effloresce and be innovative, there must be a degree to which ideas are accepted by discipline peers. For ideas to be understood and accepted by peers for publication, three conditions must suffice: As innovators they *shall*:

a) **Demonstrate** that they have adequately followed the discipline coda or scheme upon which knowledge claims are based

b) **Communicate** those ideas in order for them to be accepted

c) **Evidence** the above process which can include, but is not limited to publications in books, journals or conferences. The quality measure is per the standards bodies in the field, inter alia.

In the GE-KAM, A, B, and C appear linearly progressive. First the graduate students are able to understand and Demonstrate they have the intellectual capacity to follow the disciple coda upon which knowledge claims are generated, but also generate new ideas. In the lab, it may take the form of understanding technical papers or providing reviews of others’ work and working with the supervisor to provide solutions to industry questions. However, students must then have the intellectual capacity to synthesize *ways of knowing* with *ways of representing knowing* – they must Communicate claims according to discipline or industry standards so that others; colleagues, peers, clients, etc can quickly grasp proven truths as separate from novel or innovative contributions. Evidence of processes A & B can include publications or patents.

The definition postulates that innovation in graduate engineers is about the capacity of students to get research work (outputs) accepted by the academy. Thus, innovation is intrinsically tied to capacity—the capacity of the Network to function well, the capacity of the Social to be successful in showing engineers how to communicate and the knowledge to facilitate the creation of new knowledge. If I consider these three ecologies I can now append skills and capacities which are derived or are outputs / qualities of student dwelling each of the Ecologies. How these capacities map individually to each Ecology is discussed below in “Zones of Development”. I suggest that the degree to which students possess the skills in each Ecology likely will suggest the capacity for innovation beyond the scope of academia.
Zones of Development

The thesis subtitle: how does the graduate engineering student innovate? is summarised above in the definition of innovation in graduate engineering student training. This definition involves a reconceptualising of research as the knowledge acquisition process demonstrated precisely by the GE-KAM. The GE-KAM is process rather than product; working toward capacity or potential versus a specific deliverable. The tangible sign of capacity is the alignment of students toward innovation by the increasing acceptance of one’s work within a community. Whether the graduate eventually goes into industry or remains within the research network, they will need to possess capacity. Capacity in each Ecology involves unique qualities. The qualities are distinct from attributes or skills in the following way—a skill or attribute might be the skill to use MATLAB, or to program in C++, or implement an algorithm using the Fast Fourier Transform (FFT). Capacity sits above skill, as in the capacity or ability to teach oneself new operating systems or numerous algorithms. Hierarchically, above capacity might be personality traits such as “strategic”, “leadership”, or “entrepreneurial” –abilities which are as much a function of engagement, practice, and experience as they are training. A person with capacity can attain skills and, in time can become a leader, or entrepreneurial or strategic. Each of the Ecologies I have discussed has the potential to model (or teach) specific capacities. Each Ecology will be discussed in turn.

Network

The Network capacities involve possessing abilities to:

a) **Convince others of the thoroughness and rigour of the work.** This is suggested by the importance the supervisor places upon having at least one journal paper in a top journal for each graduand.

b) **Communicate verbally (presentations) and in writing (reports or publications).** This is suggested by the importance the supervisor places in requiring frequent technical reports of the students, both verbally and in writing.

c) **Flexibly transcend discipline boundaries to implement ideas.** This is evidenced frequently in the work of students who assist the supervisor in tasks or projects which are analogous to the work, but are not directly linked. I witnessed this with Zahir, as he not only assisted the supervisor in administrative tasks and lecture preparation, he also went on to work in a technical area not directly related to his thesis.

d) **Leverage learning and ideas of others.** Several students such as Tom and Brad realised the ultimate value their colleagues brought them in leveraging and learning from others in the laboratory.

Network capacities necessarily involve the ability to foster and leverage knowledge among peers, to transcend discipline boundaries to understand others’ points of view and ideas, and to convince increasingly larger groups of stakeholders about the thoroughness and rigour of the work of the team. This capacity in academia is somewhat different from that in industry. In industry, network capacity means also the ability to negotiate divergent needs internally and externally. This is extremely important for the Companies ability to profitably satisfy the needs of the client.
Social

Social capacity involves the ability of individuals to:

e) Work independently. Note below the dichotomy between the independent vs dependent student/employee.

f) Undertake mundane tasks not directly related to projects while maintaining a focus on long range goals. While this may initially seem unimportant, there will always in academic and industrial settings be the requirement to undertake routine paperwork or administrative duties. Realising this fact and learning to accord the importance of administrative tasks vs engineering ones was something I witnessed in action in industry.

g) Realise limitations of existing knowledge & how to acquire new knowledge. Note this also is a quality of independent vs dependent students/employees, and is detailed below.

h) Collaborate, communicate and compromise in teams. While I noticed this occurred with the students when they wanted to do social things together, I certainly witnessed most collaboration, communication and compromise in the Company. Here it was a daily requirement of all team members; especially when the pressure is on to complete or get something out of the door.

Social capacity involves the ability to integrate teams of co-workers and even outside stakeholders quickly in order for joint ventures or teaming agreements to function unilaterally. In Australia, the term for this movement between and among teams producing entrepreneurial results is called being “fleet of foot”. In the US, the term nimble is applied to this ability. As noted above, it also means that individuals recognise times when more mundane, independent or research project work is required for planning, risk assessment, etc. An example of social capacity is Zahir’s ability to move into an industry which requires him to manage accounts in the following markets: France, Russia, Central Asia and Belgium, and as he says:

My daily work is more the thing that I enjoy doing. Dealing with people, rather than with computers, managing projects and negotiating contracts rather than writing theoretical papers. Counting millions in projects (real millions) rather than deriving and checking theoretical Cramer-Rao bounds [personal e-mail correspondence, June 2008].

Knowledge

Knowledge drivers in the knowledge Ecology should posse, at a minimum, the ability to

i) Work within existing paradigms but also use alternative approaches when problem solving. This is commonly called the ability to think laterally. By definition, it requires the ability of a person to identify gaps in their current thinking or ability, and to obtain that knowledge. This also is discussed below as the evidence of an independent
researcher. Opportunity to use this skill comes with increasing project work or design development in industry.

j) Compromise to have ideas accepted or allow ‘pull’ from development or implementation teams. As discussed above in the social driver, much of what is accomplished in industry is about compromise. But this is also true in the academic world. Dock notes that the greatest disappointment is:

“The most disappointing thing...is uhm...disappointing...what I can see...in my experience from PhD is that many things you expect cannot be met in real PhD life and because there are many things you think you can do...and after [you find] that is not going to work. For example, the idea cause you can have a lot of ideas...and then uhm it may not work...or you may not have justified or a numerical issue, or things like that...so it can be very tense. When you are doing work in a PhD...with PhD you have to try and fix...”

k) Discern and defend significance and originality of ideas. As noted below, this is a prime determining factor of an independent student/employee.

Students who have the capacity to work within existing paradigms, but also are not so rigid as to insist upon their own time frames, documentation requirements, and will thus allow ‘pull’ from externalities (design, development, test, implementation or sales teams) are highly desirable in industry. A keen sense of discernment as well as an ability to use alternative coda and defend ones ideas to others are crucial. An example of the ability to use alternative coda is my ability to publish in both Education and Engineering for example.

The above list was derived initially from a graduate attributes listing in the literature (see for example: Bortwick and Whissler (2003)), but it must be stressed that the capacities as I have re-intepreted them are of a higher level than most generic attributes suggested in the long standing Australian discussions about Graduate Attributes such as advanced skill in referencing, good literacy and numeracy skills, technically competent. My proposed attributes point directly to relevance for innovation in industry, are derived from my data, but also my experience in industry itself. In addition, the careful reader will note how at least one, if not several of the attributes in each of the Ecologies discussed above contributes to an independent student/employee, as more fully discussed below.

If students achieve several capacities in each of the Ecologies, I can predict they will be successful, even if they perceive an overall negative experience in their PhD program. For example, in the thesis, Zahir retains a negative attitude of his experience. However, as painful as the lessons were to him, he is a successful engineer in an international corporation, where he uses all of this—the approach and Networking, Social and Knowledge Ecologies as he fights for a position in the corporate boxing ring:

I can try to understand those who do politics for a contract of several millions, but I don't want to try to understand those who do it for a paper... Now if one likes to compete and get money or whatever, well go ahead and start a company and see if you can fight to survive. Professors know a lot, but they are seldom good fighters. They are trapped in the comfort of their auto-prestige and expect a bit too much from their status. Professors in their modern Western version are not my model. Well now I'm in industry and business, far from academia... well I'm served... politics, mobbing, money
and so on... all is here and sometimes it irritates... but in contrast to academia, my expectations were realistic... I didn’t expect fairness here anyway... here we fight daily.... here we learn daily....

Zahir knows the rules of engagement in industry. He knows there is nothing fair about it, but industry doesn’t pretend to be anything other than what it is. For Zahir, industry is where he learns daily. Academia is somewhat different. Both Zahir and I learned valuable lessons when we left academia and immersed ourselves in industry. Our independence allowed us to immerse ourselves, to demonstrate our creativity:

Applied creativity and innovation facilitation do call for immersion in experiential processes just like that of the arts. However, the results of this process are built on disciplined observation and reflection with a strong emphasis on interpretation of the personal creative insight – rather than the unknowable insights of a distant champion. Both share a mental discipline, but contrary to popular opinion, the artistic path is the far more knowable and attainable route. (Business and Higher Education Round Table, 2006, p. 4)

Zahir and I experienced firsthand what we dreamed of in our respective PhD programs—the ability to transcend our individual experiences in our given disciplines, and move into new areas—for him, it was technical sales, and for me, it was technical writing. However, neither of us might have been able to do this had we missed the lessons of the PhD in each Ecology. We became independent thinkers, self-taught learners, with decreasing reliance on others to control the flow of work and ideas. What characterises independence? Let me begin by saying that dependence or independence are subjective terms. From my observations, interviews and the literature (Kam, 1997) (Business and Higher Education Round Table, 2006) there are several traits that suggest a student is dependent.

1) **Relies on supervisor for structure, ideas and deadline-setting.** This was evidenced when the supervisor noted “The first paper is a disaster, I have to write all over it, you know and I fix it here and there because the structure is missing.” He used similar words when he was discussing Safwan’s talk—‘the talk was just a disaster’. Some students I knew from the lab required supervisor structuring and ideas through to submission of thesis.

2) **Does not complete tasks without prompting.** This was particularly evident during the times in the laboratory when the supervisor was away in Great Britain. More avoidance behaviour occurred during this time, as suggested by the following:

   ...when I left them, I realise today still, and this is the second meeting since I have been here, and I realise they, they need that coaching, they need support and vision, they need it, they desperately, they are just alone and floating somewhere where they don’t know what to do and are glad to have the supervisor back because I am back, in the usual way.

3) **Is unable to identify gaps in knowledge or opportunities.** I came to understand that independent students were increasingly able to know and identify what they didn’t know. This was particularly noticeable when the students repeatedly answered that their “systematic attacking the problem” was the single most important thing they would take from the thesis. Recall Mark’s response to this question was: “Knowing how to teach myself what I don’t know.”

4) **Often is caught up in details, rather than being able to transcend minutiae for a broader range view.** If one takes Tom as a rather dependent student, recall that he
was stuck for three full months trying to find the problem with the duplicate line in the code.

Dependent researchers can form excellent team members, but cannot necessarily transcend discipline boundaries with the ability to see a problem from a 30,000 ft view. An industry based team, focused on commercial results would not have tolerated Tom’s three month delay with the algorithm. However, a dependant researcher, given the ability and relevant opportunity can attain the capacity to be an independent researcher and leader. Given my experience in industry, I am able to articulate some of the qualities of independent innovators:

- **Conceptualises outcomes of projects and knows sequence of events in order to complete them.** In industry, the ability to envision the outcomes of projects, and know the steps toward completion of the project is certainly crucial. Lance Birdsall, the commercial diver who assisted on the UHC project in design, fabrication and project implementation certainly evidenced a keen ability to imagine the use of the UHC in situ. On a smaller scale, Dock shared how a paper was constructed.

- **Recognises derailing or sidetracking tasks and is able to avoid them or minimise impact on work flow.** Dock was certainly able to conceptualise his thesis and the milestones along the way; avoiding as often as possible ‘disruption, disturbance and things’. In industry, it is crucial to avoid downtime due to operator error. This is true on both the factory floor and in project implementation, as have seen several times.

- **Ability to self-rank numerous projects by importance and/or requirements and ensure completion.** Frequently I noted independent researchers and employees would be able innately know which projects required more time, attention. These people would be able to ramp up one project while keeping momentum going on others. In fact, I was able to model and replicate this to my ultimate benefit at the Company because I have been frequently called to do a number of projects with multi-changing resources or completion dates; brining all off as appropriate.

- **Recognise alternative or novel approaches.** On several occasions during the design and manufacture of the UHC, the engineer or diver realised that something wouldn’t work. Firstly, the UHC was originally conceived of as two halves of a clam shell which would clamp over the pipeline. Lance was able to see that the weight of the clamp would be too great for the circumstances of the land based crane to lower it over the affected piece of pipe. Todd saw that the clamp might buckle under external water pressure and added the stabilising fins. Finally, after fabrication, Todd saw that the clamp was misshapen at its penetration points, and sent the UHC for Post Weld Heat Treat, which effectively smoothed over imperfections caused by the changes in design scope.

Above I have characterised what a student or employee who has the capacity for innovation might look like. I have shown how students must attain capacities in each of the Ecologies: Network, Social and Knowledge in the GE KAM. I have demonstrated, I believe unequivocally, there is an interlinking of obtaining skills in each of the Ecologies and independence. When is the Magic Moment when the student changes, is transformed from dependent, lacking skills in all Ecologies, to independence? When is the defining moment in the career of the student when they gain voice, authorial? Literary? Scientific? It is different for all students, and never occurs for some. For Zahir, it was a violent process. For me, not so much. I had gentle mentors. However, if transformation does occur the student will become an independent researcher or employee as evidenced in the criteria above. Let me revisit my
definition of innovation at this juncture as it is useful to contextualise it in terms of the above referenced skill set and the transformation:

**Innovation in graduate engineering student research effloresces in the acceptance of ideas by discipline peers and potentially society.**

Innovation is essentially impossible unless there is a personal transformation from dependency, needing to be fed ideas and timeframes, to independent, autonomous thinking and self-discipline. All manner of ideas and notions might exist out in the time space continuum, but without transformation, self-disciplined and organised critical inquiry, followed by writing according to some defined coda, and FINALLY acceptance by peers; innovation in the academy cannot effloresce. My discussion and claims about this significant conclusion are legitimised by two students, Zahir and myself, who have rather successfully taken our capacity from our PhD experience, published according to the coda, but later immersed ourselves in the new culture of industry, and TRANSFORMED OUR APPROACH and “systematic attacking the problem” to facilitate or at least contribute to commercial innovation. This can be justified and understood because, unlike knowledge only for knowledge sake, decontextualised and without cache in the written scriptures, Zahir and I evidence a transformation, a transformation so profound and well understood that we can both write for the academy AND dwell deeply in industry.

**Situated Learning and Communities of Practice in Industry**

The following discussion concerns the application of concepts of Communities of Practice to educational and industry settings. It dwells deeply in Lave and Wenger’s concepts from *Situated Learning: Legitimate peripheral participation* (1991) and *Communities of Practice: Learning, meaning and identity* (1998) The largest part of this thesis has been to demonstrate how graduate engineers innovate. But how did I come to know how they innovated? I defined innovation in graduate engineers because I saw innovation in action in industry. It was in this juxtaposition, this flexion to and fro that I was able to see very clearly what I might have missed otherwise. I am very lucky to have had two distinct ethnographic experiences. Because this thesis could not, wasn’t complete until I dwelled in industry, I must attend to that, and offer the reader a glimpse into those privileged spaces also. I do this via exploring Situated learning in educational settings vs industrial settings. Lave and Wenger are my continued reference points. In the following, I first discuss learning in educational settings. As a segue to the application of the learning theory to industry, I discuss my experience at the Company. It was as much my learning experience about them, as it was them actively innovating. I then attempt to apply educational setting CoP learning theory to industry.

**CoP in Educational Settings** The concept of Communities of Practice (CoP) as applied to an educational setting is demonstrated in many ways in this thesis about graduate engineers in the laboratory. I demonstrate apprentice learning where:

The notion of situated learning now appears to be a transitory concept, a bridge, between a view according to which cognitive processes (and thus learning) are primary and a view according to which social practice is the primary, generative phenomenon, and learning is one of its characteristics. (Lave & Wenger, 1991, p. 34)

The GE-KAM has only one learning Ecology—the Knowledge Ecology. The other two are both socially bound—the Network and Social Ecologies—involving social practice as the ‘primary, generative phenomenon’. (Jackson, 1998) These Ecologies serve as a stage upon
which the students act and interact, and to transition one’s work and one’s self to larger and more complex webs of significance, spheres of influence outside of the lab. Lave and Wenger note:

In contrast with learning as internalization, learning as increasing participation in communities of practice concerns the whole person acting in the world. Conceiving of learning in terms of participation focuses attention on ways in which it is an evolving, continuously renewed set of relation; this is, of course, consistent with a relations view, of persons, their actions, and the world, typical of a theory of social practice. (Lave & Wenger, 1991, p. 50)

Both the Supervisor and the student have equal hands in the Social Ecologies, the students to control the interstitial, intimate spaces of the lab within their Social Ecology; and the Supervisor to control the relationship to the outside in the Network Ecology. Recall that the Supervisor mentioned that one of his most rewarding experiences was when another academic would come to him at a conference or elsewhere and compliment him about his students who have made their way in the academic world. This is a prime example of the function of the Network; to, in a sense, join the hand of the student to the hand of the academy. As long as the laboratory maintains somewhat of a stratification of new apprentices and more experienced sea-dogs, peer learning can proceed as Lave and Wenger suggest:

The diversified field of relations among old-timers and new-comers within and across the various cycles, and the importance of near-peers in the circulation of knowledgeable skill, both recommend against assimilating relations of learning to the dyadic form characteristic of conventional learning studies. (Lave & Wenger, 1991, p. 57)

In terms of learning, using the old metaphor of ‘filling up an empty jug’; there is very little in this kind of dyadic teaching evidenced in my thousands of hours of observation, field notes, and interviews. As much as can be observed, students learned the most when they were in dialog with post-docs, those students who were two plus years further on than themselves. Brad is very clear in making this case. Lave and Wenger are also careful to indicate that the very act of replicating work, being introduced to the outside world, has the effect of re-writing the academy: “…the centripetal development of full participants...also implies the replacement of old-timers...Indeed, I must not forget that communities of practice are engaged in the generative process of producing their own future.” (Ibid) It is interesting to note that the act of replicating, replacement of old is seen as movement, process, and centripetal force. The centripetal force is compelling in terms of long-term viability of stable disciplines and professions, such as midwifery, academia and butchers. It offers less purchase for those who wish to “border cross” into other areas. If the whole burden of what the academy does as educators is to enculture or assimilate others into Communities of Practice, what model can be proffered to students who want to break away from the centripetal motion of the galaxy of academia?

**CoP in Industrial Settings** Importantly, will the same nurturing models of apprentice learning, Communities of Practice and zones of proximal development apply in the new culture? Can / should the student expect the same ‘care and concern’? afforded them in the intimate student spaces? This raises important questions about the viability of transferring the promise of Communities of Practice (CoP) to Industry. It provides some complexity which one might not initially predict that I address at length below.

To begin, the ultimate goal of industry is not, in fact, to make employees. They are not puffy organisations whose missions include creating inclusive learning spaces which are
personally transformative, evidences by sustained learning and mutuality. Industry hires skilled workers for doing pre-scribed work. They do not want apprentices. Wenger in Communities of Practice: Learning, meaning and identity (1998) lends insight into how concepts of CoP can be related to industry. Primarily, CoP can be applied via conceptualising learning in practice:

The concept of practice connotes doing, but not just doing in and of itself. It is doing in a historical and social context that gives structure and meaning to what we do. Such a concept of practice includes both the explicit and the tacit. It includes what is said and what is left unsaid; what is represented and what is assumed. It includes the language, tools, documents, images, symbols, well-defined roles, specified criteria, codified procedures, regulations, and contracts that various practices make explicit for a variety of purposes. But it also includes all the implicit relations, tacit conventions, subtle cues, untold rules of thumb, recognizable intuitions, specific perceptions, well-tuned sensitivities, embodies understanding, underlying assumptions, and shared world views. Most of these may never be articulated, yet they are unmistakable signs of membership in communities of practice and are crucial to the success of their enterprises. (Wenger, 1998, p. 47)

What Wenger describes above is business know-how, ways of going which are the specificities of corporate culture. These relationships, tools and dialects are born, fostered and die in organisations in an organic way which is much in response to financial drivers. If the company is in rapid growth mode, it is re-born anew each four to six months. The playing field for employees is different from week to week, and change is more normal than stability. Teaching the culture which is changing rapidly to others is the furthest thing from the ‘old-timers’ minds. Creating personally transformative places for sustained learning would be low on the priority list when compared with billable hours, end of month close, lost time recordable accidents, margin, mark-up, the latest P & L, recruiting quality staff and quarterly drug tests. From an employee point of view, there might not be any training and there are few written policies. Because this is the corporate culture, employee expectation of management is minimal. Management expects employees to fulfill the niche for which they were hired, and little else. The reader should not have a vision of this company as draconian and parasitic. These are pragmatic, financially driven considerations, not emotive ones because it is industry’s job to make money, nothing more. Wenger recognises this other sort of participation:

What we recognize has to do with our mutual ability to negotiate meaning. This mutuality does not, however, entail equality or respect. The relations between parents and children or between workers and their direct supervisor are mutual in the sense that participants shape each other’s experience of meaning. In doing so they can recognize something of themselves in each other. But these are not relations of equality. In practice, even the meanings of inequality are negotiated in the context of this process of mutual recognition. (Wenger, 1998, p. 56)

Elements which industry value are those factors which facilitate the delivery of goods or services to the specific needs of the client at profit to the industry. It does not need the team to like each other or for consensus to be the ultimate goal, a fact that Wenger also highlights: Participation is not tantamount to collaboration. It can involve all kinds of relations, conflictual as well as harmonious, intimate as well as political, competitive as well as cooperative. (Wenger, 1998, p. 57) What I observed in industry absolutely aligns with this. Conflict is a daily occurrence, and frequently it is from this conflict that innovation occurs. Also, departments are ever competitive in seeking support, money, staff. From this competition, and through dialogue, again innovation occurs. Learning what battles are winnable, knowing
how to compete and argue, and with whom, are valuable lessons. These employees do need to be familiar with each other. They must win some battles and lose some, they must talk, agree, disagree, share resources, win contracts and lose them. In short they must be engaged in dialogue:

It is because they sustain dense relations of mutual engagement organized around what they are there to do. Being included in what matters is a requirement for being engaged in a community’s practice, just as engagement is what defines belonging...In order to a be a full participant, it may just be as important to know and understand the latest gossip as to know and understand the latest memo. (Wenger, 1998, p. 74)

In our academic lab of signal processors, it is plausible to say that the lab functioned as a group of peer learners. They did not have the on-going presence of the Supervisor. In fact, he was often absent for months at a time. This certainly was true with my supervisory experience. So is there something mutually exclusive here? In industry, Communities of Practice must sustain ‘mutual engagement around what they are there to do’. In academic settings, is ongoing engagement important? Is it required at all? Lave and Wenger themselves suggest in Situated Learning:

Nor does the term community imply necessarily co-presence, a well defined, identifiable group, or socially visible boundaries. It does imply participation in an activity system about which participants share understanding concerning what they are doing and what that means in their lives. (Wenger, 1998, p. 98)

In industry, two factors are mandatory. For learning to occur, initiates must have unlimited access, not to peers, but to those who have already been initiated, who already have full membership in the community. For innovation to occur, there must be sustained dialogue which is dialectical in nature and which transforms, translates, the thinking of both parties. In a discussion of a project our Company executed in 2005, I was able to see innovation as it happened. The following is a brief synopsis of that project.

The Underwater Habitat Clamp (UHC) Project

“Can you write something for a conference?” Mark asked me one Autumn day in 2007. I had only worked at the Company for about a month, but I was game for anything. “You bet!” I agreed. “That is my bread and butter,” I chirped. It was the beginning of an ongoing collaboration with myself, the commercial dive supervisor, Lance Birdsall, who ran the job, and the representative of the Enbridge Energy, Adam Erickson. Since that time, two academic papers and one industry article have arisen. Mark Berge, then General Manager (and diver), had been, as much as anybody, the driving leader of the project. It was he who brought the fabrication team into the project to engineer the novel pressure vessel, it was he who recruited Lance Birdsall, thus he is a co-author of the resultant publication: Underwater Habitat Clamp: an innovative partnership in pipeline repair

The writing of the fully refereed paper for American Society of Mechanical Engineers (ASME) was discussed at some length above in “The Story of Tanya”. However, the following will concern the innovation process which occurred with the design and fabrication of the UHC and the subsequent implementation of the project for the client, Enbridge Energy. The purpose of the discussion is to demonstrate participation in action.

In order to write the paper, I was given unlimited access to whatever I required to accomplish the task. Hence I had job files, production photos, design drawings, access to
divers who worked on the project, access to engineers who designed and fabricated the UHC, and access to the client. This allowed me, in an intersubjective way to reconstruct fully the innovation process. The dive superintendent, Lance Birdsall and the engineer Mr Todd Marohl became my key informants, and I had many hours with each of them to help me understand the UHC project, design and implementation. The project for the client, Enbridge Energy, was actually multi-staged. Veolia had worked with Enbridge Energy in previous projects where commercial diving was required. The first stage of the project was undertaken when Enbridge discovered an anomaly in a section of underwater pipeline in the headwaters of the Mississippi. The anomalies provided no immediate threat of release of product to the environment, but rather required a ‘patch’ until a permanent solution could be determined. Because Enbridge had worked with the Company recently in the Straits of Mackinac, it was logical that for the temporary repair, Enbridge might contact the Company. The temporary repair of the section of pipe was completed in 2004. This involved the installation of a PLIDCO Split + Sleeve clamped and sealed over the affected section. Such a repair is sometimes considered permanent by oil companies, however, Enbridge specified a repair which involved certain welding techniques in a dry environment. The Company was engaged to find an adequate solution. The details of the numerous parameters which the solution must suffice were succinctly written in the paper’s “Scope of Work” (Berge, Birdsall, Erickson, & Vernon, 2008): from (Berge et al., 2008)

3.1 Scope of Work

The initial scope of work had several parameters. Of highest priority was a dry environment due to Operator specific requirements for a welded sleeve and the need for the Operator’s welders to complete technical aspects of the project. Prompt execution of the project was certainly important and later became more of a factor as winter approached and ice was more prevalent. The site provided additional challenges in the way of deployment of a habitat, particularly the current of the Mississippi, which was at right angles to the pipeline. Deploying a barge equipped with a crane in the narrow headwaters of the Mississippi was not considered feasible. Therefore, a land-based crane to lower the habitat was considered most desirable and as such the UHC had certain weight restrictions. The seabed was also of considerable importance in the design. The seabed at Bemidji was uneven hard pack sand. Two pipes, at the same depth as the affected pipe, were in close proximity and provided additional challenges.

While not an integral consideration, the length of the habitat was originally designed to encompass an 8 ft long repair sleeve with the capacity to have a technician work either end.

Upon consideration of the problem, the Company’s senior divers assessed the scope of work and, rather than design a traditional single-use habitat, they considered a multi-use habitat. Thus, additional parameters were added to the scope of work:

- **Adjustable aperture for variable pipe diameters**
- **Depth from 15-33 feet (later modifications for true hyperbaric)**
- **Mobility—had to be easily transported and deployed from land based crane**
- **Weight (in compliance with capacity of the crane, buoyancy and stability)**
- **Seabed—uneven, legs needed to be adjustable**
- **Transportable by truck on US highways under a wide-load permit**

Quite early in the design, the vessel was identified as a confined space. A confined space is defined as one with limited or restricted means of entry or exit, is large enough for an employee to enter and perform assigned work and is not designed for continuous occupancy by employees. Because the UHC was specified to accommodate two welders, a welder’s helper and an inspector, a number of confined space safety requirements were identified. Two manways were incorporated into the design, as was an emergency man-rated lifting device, smoke extractors, fresh air ducts and atmosphere monitoring equipment and additional provisions for confined space rescue of personnel in the event of injury to an occupant.
Underwater habitats are a general approach to underwater pipeline repairs. The solution required by Enbridge was specialised, and notably required no shutdown of the affected pipe. The project commenced with the Company in April of 2005. The design phase lasted from April to June. Following this, manufacturing occurred from July to September. Final fit-out was completed in September-October, and the UHC was deployed to the job site in November. Though site and pipeline preparation took approximately three weeks, welding on the pipe anomaly was completed in one day. During the design phase a number of issues came to light. Firstly, the UHC was initially only designed to have one top mounted man-way. A manway, in this case was a section of pipe which allows workers ingress and egress to the habitat. Later, through discussion between the divers and the engineer, it was determined that UHC is a confined space which required more than
one manway, one to carry the requisite cabling, welding gases, fresh air return and electricity and one for worker access or emergency rescue. Re-engineering was required to accommodate the addition of another manway or “spool piece” at the opposite end of the UHC. These were engineered to be detachable for easier transport.

The UHC was initially designed to be of lightweight construction in order that the UHC may be lowered by crane to the affected pipe area in the Mississippi. It was discovered via calculation that, in fact the initial designs were too light, and the vessel would fail under water pressure of one atmosphere. So, stiffeners or fins were added. Too, accommodation was be made for the sealing surfaces—the places where the bottom doors met the top. Not only did the UHC need to be fully watertight, the bottom doors and legs were operated by hydraulics, and catchpoints for these had to be designed. Due to the many changes, the engineer admitted to me “There were so many changes and the UHC was so miss-shapen, I thought it wouldn’t work. So we decided to heat-treat it.” Heat treating, or Post-Weld Heat Treat (PWHT) has the effect of smoothing out some of the imperfections in weldments and shapes.

After the completion of fabrication, Lance Birdsall, the commercial diver who consulted from the beginning, designed and tested and installed all of the sealing surfaces as well as the hydraulics. Tests and emergency rescue procedures were practiced in a dry run in October, and the UHC was trucked overland from Appleton, Wisconsin to the deployment site in the Mississippi. From my understanding, and from reading between the lines, it was the continual interplay, arguing between Todd (Archimedes) and Lance (the Diver) that resulted in the safe and effective execution of the project. To me, Lance had to translate the real requirements of commercial divers to Todd, and Todd had to translate the needs of design and fabrication to Lance. It is in this translational dialogue that goes round and round that makes innovation happen. The key is not to have someone, a peer, with the same skills as you, but to have someone with a different skill set and/or a higher level of skills. Knowledge acquisition is not then just participatory, but a real bootstrap—going from not knowing something at all to applying it in action. Wenger himself recognises the phenomenon of translational dialogue:

When information does not build up to an identity of participation, it remains alien, literal, fragmented, unnegotiable. It is not just that it is disconnected from other pieces of relevant information, but that it fails to translate into a way of being in the world coherent enough to be enacted in practice. [Emphasis added] (Wenger, 1998, p. 220)
I define translational dialog as the process by which competitive needs of experienced teams arrive at negotiated compromises between engineering and functionality and other constraints such as client requirements, cost, time to complete, etc. Translational dialogs translate knowledge or view point of one person into something knowable, acceptable or usable by the other. In the case of the UHC, the translational dialog took place between the Principal Engineer and the divers over a period of three months, with the ultimate outcome an innovative and successful project. Translational dialogs usually require close proximity of the participants, and frankly, do not require that the participants are part of the same team, merely that they have immediate access to each other in order for dialog to occur. (Vernon & Werner, [2009]) The evidence of translational dialogue in industry is the commercial viability of projects. Rarely are the magic moments of industrial innovation written, as in codified knowledge. Team members retain the tacit knowledge for further use, but writing is infrequent; quite an opposite sort of innovation than academia.

Translational dialog and the academy What does translational dialog hold for learning environments? Is translational dialog difficult to achieve in educational settings? As noted several times, dialogues between peers can and did occur in the laboratory I observed, but the translational aspect of these dialogs is weak for the student. In industry, engineers and practitioners from the field engage in frequent dialectical rallies in order to deliver quality solutions to clients. When neophytes, such as myself, have full access to information, files, photos, plans, and importantly, more experienced engineers or practitioners, we too are involved in a translational dialog. Is the failure of graduate students to be innovative in a traditional sense because there are shortages of translational dialogs in the laboratory, because students have minimal access to those with complimentary or higher skill sets than themselves? I am not sure there are direct corollaries, but equally I cannot rule this out as a possibility. Lave and Wenger report:

To the extent that the community of practice routinely sequesters newcomers, either very directly as in the example of apprenticeship for the butchers, or in more subtle and pervasive ways in schools, these newcomers are prevented from peripheral participation. (Lave & Wenger, 1991, p. 105)

There is much to be said about denying and granting access. At the Company, I was given unlimited access to the information as required AND I had unlimited access to the various higher skilled professionals. Information was available for the asking. In academia, a kind of denial of access does occur—not usually malevolently—but because the students themselves don’t know what they don’t know. They don’t know, generally what info they need to corral, what questions are relevant and what aren’t. This is why peer learning and legitimate peripheral participation offers much as a way of negotiating these dangerous waters. But it is a slow way, compared to the offerings of translational dialog. If the Supervisor is a hands-off supervisor, rarely available in the lab, and really only interested in building his academic ivory castle, in short, if he is really only interested in the Network Ecology, then the student is legitimate, but not engaged enough in practice for meaning to be made. Wenger reiterates:

The standing of the master in the community is therefore crucial. Today, doctoral students have professors who give them entry into academic communities. Granting the newcomers legitimacy is important because they are likely to come short of what the community regards as competent engagement. Only with enough legitimacy can all their inevitable stumblings and violations become opportunities for learning rather than cause for dismissal, neglect or exclusion. (Wenger, 1998, p. 101)
Should there be different flavours of legitimate peripheral practice, one for educational environments, grounded in theory, and one for industry, grounded in profit? While I would tend not to want to complicate the social learning theory of either Lave or Wenger, I see no real choice because Communities of Practice does not adequately account for the meanderings, the sniping, the shouted arguments behind closed doors for which no apprenticeship in the academy ever prepares one. It does not account for the quantum leaps that take place when neophytes have unbridled access to information and people and witness the *translational dialogues* between complimentary disciplines—e.g., the divers and Archimedes for example. To this day, Archimedes and the diver aren’t friends. They can meet, make decisions, but rarely talk; even just ‘small talk’. But without each other, the UHC would not have happened. I am reminded by Wenger’s most eloquent of statements in *Communities of Practice*:

In this interplay, our experience and our world shape each other through a reciprocal relation that goes to the very essence of who we are. The world as we shape it, and our experience as the world shapes it, are like the mountain and the river. They shape each other, but they have their own shape. They are reflections of each other, but they have their own existence, in their own realms. The fit around each other, but they remain distinct from each other. They cannot be transformed into each other, yet they transform each other. The river only carves and the mountain only guides, yet in their interaction, the carving becomes the guiding and the guiding becomes the carving. (Wenger, 1998, p. 71)

The sense I make of this is that yes, I do propose that in Communities of Practice where the desired result is more than learning, where there is an economic benefit that is a formal, if not written requirement, that *translational dialogue* is a necessity. This hypothesis is merely taking the Community of Practice of claims processors to the next level—that of bootstrapping learning with the ultimate aim to evidence a commercial outcome.

![Figure 6: UHC lowered by crane over the affected pipeline](image)

Note commercial diver, far left ready to deploy in the icy headwaters of the Mississippi.
Sacred Knowledge

The trinity of Social, Network and Knowledge Ecologies. In this section, I discuss my chosen title for the thesis: Sacred knowledge. Is the title an oxymoron? What is the meaning of Sacred knowledge for my context? Finally, and in summary, I discuss my personal journey in relation to innovation. From dwelling deeply in the places where engineers learn, learning myself and being involved with industrial innovation, I suggest a possible intersubjective research methodology which is based upon the concept of intersubjectivity defined by Michael Jackson in Minima ethnographica. I conclude the thesis by suggesting that to learn to be truly innovative, engagement in intersubjective learning, dwelling in and dwelling on is required.

The question I addressed above was how does a graduate engineer innovate? In this, I actually re-defined innovation for graduate engineers, and how innovation for them, and ultimately society, is more about process than product. Industry cares little for process as long as it results in commercial success! In the following, I discuss the concept of Sacred knowledge, why I chose it as a title and what it means for the study. In the case of the students I worked with for nearly five years and have known for over a decade, I like to think of our journey as coming to knowing. This journey, not to confuse our metaphor of the quest of Ananse, is also similar to the preparation of one’s life as a member of the clergy. What I saw in the laboratory was that signal processing became a ‘calling to faith’ for the students, and their training equivalent to seminary. They prepared the manuscripts at the foot of the priest, offered them up, and if deemed accepted, presented them to the congregation. Also, the students seemed ever seeking the approval of the senior cleric, the Master, the bishop. This metaphor seemed also to extend to the realm of celebrity; relationships were never discussed when I was within ear shot, other than perhaps in passing reference. The metaphor of priestly life is one which I didn’t originate (Frow, 1988), of course, but if one accepts a sacred, theological metaphor rather than a profane one, the quest for knowledge is imbued with a moral and spiritual goodness. This goodness of attaining the Canonical Law, or PhD, is a real thing, particular to, I am not playing stereotypes here either, for such discussions about redemptive power of education to change one’s position in life, occurred several times at our lunch meetings.

So this appears ironic-- the students, many of them, are faithful devotees of Islam, Buddhism, and Catholicism (the sacred), as well as the religion of signal processing (the knowledge). Sound scientists, technical and rational, yet faithful practitioners. Schön notes:

...The engineers, closely tied to the development of industrial technology, became a model of technical practice for the other professions...As the scientific movement, industrialism, and the Technological Program became dominant in Western society, a philosophy emerged which sought both to give an account of the triumphs of science and technology and to purge mankind of the residue of religion, mysticism, and metaphysics which still prevent scientific thought and technology practice from wholly ruling over the affairs of men. (Schön, 1995, p. 32)

I borrow the title Sacred Knowledge from Edward Shils. Cited in Schön, Shils refers to the (then) new multidisciplinary universities such as John Hopkins, moulded on the British ideal:
There was general agreement that knowledge could be accepted as knowledge
only if it rested on empirical evidens, rigorously criticized and rationally analyzed...The
knowledge which was appreciated was secular knowledge which continued the
mission of sacred knowledge, complemented it, led to it, or replaced it; fundamental,
systematically acquired knowledge was thought in some way to be a step toward
redemption. This kind of knowledge held out the prospect of the transfiguration of life
by improving man’s control over the resources of nature and over the powers that
weaken his body; it offered the prospect of better understanding of society which it
was thought would lead to the improvement of society. (Schön, 1995, p. 35)

I detected the irony of what the students were doing vs what is commonly thought of
as engineering when I first began working with them. Thus, when I read the words sacred
knowledge I knew immediately it must become the title of thesis. It is not about the
dominance of science over religion for the students, it is about a dialectic which is resolved
between the two, in the minds of the students. Jackson cites Satre:

the rise of the intellectual accompanies the rise of the bourgeoisie, which, as a
class, feels compelled to affirm itself in terms of a global conception of the world. This
elevating demand has been accomplished by extolling analytical reason, the means
whereby a totalizing and unitary vision of the universe could be confidently
promulgated. Since no one human being can achieve such omniscience, the
intellectual has been, from the outset, someone who strays outside the boundaries of
his or her particular specialization, someone whose claims to global understanding are
as spurious as they are excessive. (Jackson, 1998, p. 190)

In the beginning, the goal, and indeed achievement, of the thesis for many students is the
completion of it! When you are awash with data and sources and stimulating ideas, it is
indeed difficult to see that the real outcome of this is not the scripture—the published thesis,
but rather the process by which one comes to that. I too fell victim to the desire to produce
the scripture, the gospel of graduate engineering study. At many junctures, I felt unworthy to
write, to give voice to the Magic Moments as dubbed by Steiner. Indeed, I didn’t experience
the magic moments until I had moved into industry. Then and only then, was I able to see the
crucifix of commercial innovation lies firmly within complex problems solved for industry by
intersubjective communication, collaboration and compromise.

In the VI Epilogue, I consider my own thesis journey and how, via an intersubjective
approach, one might introduce intersubjective methods for research. For this I consider three
themes: Commercial Innovation and the anthropological project, Intersubjective journeying,
and Learning innovation intersubjectively.

In the above section, V Findings, I have nearly brought the thesis to a conclusion. I have
written the definition of how a graduate engineer innovates. I have discussed a new concept
called translational dialogue which importantly builds upon the work of Lave and Wenger, but
applied to fast-paced engineering in industry, and finally, how, for our context, Knowledge is
returned to the realm of Sacred. In order to judge the legitimacy of the research texts I have
provided here, the reader must ask—has Tanya contributed to what is known about graduate
engineering students? Have she contributed to the stock of knowledge with respect to a
written definition of innovation? Has she contributed to the readers’ conscious experiencing
of the world and understanding of others? If the answer to these is yes, then the above
section, and indeed Tanya, has sufficed the SERVICE criterion.
VI  Epilogue

This small epilogue was planned from the beginning but in different guise. It was originally going to be my research story. It ultimately became just that, but in a circumlocutious and personal way. It is enough to say that during the writing up of this thesis I came to need to return to the USA. And that is the beginning of the end…the point at which I came to see innovation in the commercial sense. The following epilogue tells the story of how my research method and authorial voice came to change over the last two years working in industry. It builds upon The Story of Tanya, but importantly extends thinking toward an intersubjective research mode or method. The company in which I am affiliated provides services to the oil & gas industry, though has several additional revenue streams in specialised areas of high hazard explosive remediation, emergency response, environmental remediation and commercial diving. It is part of a global conglomerate, Veolia Environment, based in Paris, France. In 2008, it employed 336,000 people in 72 countries, making it the 34th largest employer worldwide. It is a Global Fortune 200 Company with revenue of $50.4 billion. My role in the company originally began as a technical writer, however, over time I have been promoted to Quality Assurance/Quality Control Manager. In this, I work with all areas of the Company and am now a member of the management team. The goal of my program is to attain ISO 9001:2008. The following is a brief story of how I conceptualise this journey in terms of my research and writing.

Commercial innovation and the anthropological project

The nature of a PhD requires the acquisition of skills which prepare the researcher for critical and analytical thought processes—being able to discern quickly the value of something based upon a set of criteria which have been defined as relevant for that situation. The intellectual method for achieving this is no different if one is a scientist or humanist. It is a complex sifting of information, some fact, some red herring, until the researcher comes to know which ways of approaching problems have, in the past, yielded more fruit. The students in my study, and my own journey suggest that achieving a PhD instills a fundamental ability to teach oneself what one doesn’t know, to do this quickly and efficiently as new schema are presented, and finally, to be able to legitimise one’s truth claims orally or in writing. This is the essence of a PhD.

Commercial innovation has some important parallels. Certain factors I have noticed facilitate innovation, but until one experiences it first hand, one has a hard time knowing what it should look like exactly. The PhD, as well, is a place to ‘dwell in’ and try as one might to find metaphors to describe the experience, it, too, remains elusive until one has experienced it first-hand. The foundation of Michael Jackson’s book Minima ethnographica resists temptations to essentialise, preferring:

In practical life what matters is not that we possess an impregnable understanding of the human condition, but that we possess an impregnable understanding of the human condition that we are able to utilize points of view, rules of thumb, and modus operandi that help us enter into more mutually fulfilling relationships with others. To this end assumed universals and notions of common humanity may, in practice, prove to be no more efficacious than assumptions of radical difference. In no society is amity a simple function of common identity. On
the contrary, sameness is often less compelling than difference, and shared language or worldview is nowhere a guarantee of empathy and intimacy. (Jackson, 1998, p. 191)

In the course of my early research, I was convinced I would locate and be able to write an algorithm for innovation in graduate students. More importantly, I was sure I would be able to deconstruct the algorithm in order to be able to teach it—to facilitate others to learn what commercial innovation is. I knew the curriculum for an Australian innovation course wouldn’t look like an American curriculum which I benchmarked in 2003 and which is currently taught in varying degrees from undergraduate to graduate level⁴. But, I was sure I could outline a course to be used in Australia.

Thus, I approached innovation, graduate education in Australia and what it means to dwell in and dwell on the particular-ness class of learning which is the PhD. I did not, however, come to know what innovation looked like until I worked in industry in the United States. This is not because PhD students don’t possess the capacity for innovation. They indeed do, as I made proof of, above. However, the fundamental problem is that the rigours of writing an academic thesis contradict the intersubjectivity of innovation. Innovation is cross pollination, diffusion, collaboration, transfer of know how where the contribution of the individuals is not simply and easily parsed as in an academic journal paper submission. In innovation, authorship is rarely sought and hardly ever taken because team members realise intrinsically that they couldn’t complete the project without the involvement of the others. Innovation is collaboration, communication and compromise.

Of these, compromise is the greatest skill in making a product, but it is the least considered in academia. Academic standards must never be compromised. Integrity must never be compromised. Rigour must never be compromised.

When I visited my Alma Mater, the University of Illinois and benchmarked the Technology and Management Program (see also footnote below), one of the lecturers who worked with the cross disciplinary teams said that the greatest challenge for the engineers, was by far, compromise. The business students, he noted, were able to make sacrifices in order to deliver on time or to allow the team to move on. He said the engineers routinely failed in this, sometimes to the detriment of the team. Steiner, in her thesis Magic Moments notes a corollary:

…in a series of case studies of innovation in a number of American firms researchers found there was little connection between basic science and innovation. They pointed out that the lack of connection between basic science and innovation was always understood by business people, but that academic scientists found this difficult to accept. (Steiner, 1995, p. 206)

While I did not completely understand this until much more recently, I did appreciate the experiential learning of the lecturer, and wanted to explore this further. It became a part of my interview question protocol for the students. The question evolved somewhat and ultimately became: What is more important? To get it done, to get it right or to do it your way? Without fail, the students in my study said “to get it right”. This is because in academia truth is the guiding beacon. Academics seek to be correct and in fact the thesis itself is a search for the truth. My search for truth was no different. I utilised standard methods for data collection and standard texts for support of assertions to demonstrate the correctness of

⁴ As noted previously, I benchmarked the UIUC Technology and Management Program, www.techmgmt.uiuc.edu, in 2003. Since then, many programs have been added across America, not only in universities, but also in technical colleges and as part of continuing education programs. The University of Minnesota has a graduate program: www.cce.umn.edu/is/ , as previously cited.
my incremental contributions to the scope of knowledge. My thesis, the written output of my solitary search for knowledge, is not compromise or collaboration. It is not intersubjective.

In a very real sense, a corpus of work such as a dissertation, the written outcome of solitary, intensive research, supported by data collected in the course of research, is the antithesis of the commercial innovation process. The very things a thesis is: tenacious pursuit of data, intellectual rigour, knowledge making and substantiating are of less value in industry than communication, compromise and collaboration.

So why does the PhD, oft touted as the pinnacle of intellectual prowess, remain the benchmark for many countries, even though surely I am not the first to note that a thesis as an artifact of research represents the opposite of commercial innovation? The answer is very simple: because the thesis represents lessons about process, not about outcomes. In a nutshell, it offers a modality to learn to think critically of information, so that thinking becomes THE APPROACH upon which communication, compromise and collaboration are layered—like transparencies. It offers capacity. The students were well able to call this out to me, even when they were still undertaking their research. As Marvan says it is: “the systematic attacking the problem”. With international students, the claim is particularly valid, especially with respect to the three c’s. Because students must learn to adapt to new societies, new grounds for communication, new collaborations; they are forced to live intersubjective lives.

When I first worked in industry after much of my PhD data was collected, my input was valued as organised, methodical and calculated. In short, I was thought of as ‘scientific’. When colleagues didn’t know the answer to something they might say (in reference to me) “Ask the PhD”. In terms of the early days in my position, there really could be very little I could offer other than the way I approached problems. I didn’t know the business lines, I didn’t know the product or even the value added with our products and services.

I have now had a lengthy immersion in the field, in industry. It was here that I had the epiphany about what innovation is for myself and students, as discussed. But, in industry I can do what I learned to do in my Australian PhD program—I can a) determine what I do not know, b) teach myself, via apprenticeship learning and mentoring, what I don’t know, but is crucial for my work and c) communicate the findings to a wider audience, even though I am not the expert. Additionally, I can filter extraneous detail from data to produce succinct executive summaries. That is the true value of the training for the PhD. The countries which value the PhD most in terms of employment in industry—such as Europe, North America, China and India, all are moving their economies to an innovation or knowledge based economy. They all demand PhD graduates, not for the narrow brand of scientific or engineering research the student happened to take as their thesis topic, necessarily, but they demand graduates with the ability to think about problems in a methodical succinct fashion, to see connections, to collaborate, compromise and communicate. The higher education institutions of these and other countries will continue to produce the ‘capacity’ for the knowledge based economy ‘load’. The challenge for countries like Australia is to produce load which will allow for the retention of the knowledge base in Australia. This, however, is a topic for additional research.
Intersubjective journeying

I am nearly a scientist
I am nearly a naval officer
I am nearly a librarian
I am nearly an academic
I am nearly an engineer
I am nearly a mother
I am nearly a writer

I have nearly been some-one, but just before I became, I withdrew or failed. I called end! and declared the story finished. Each of my “comings to be” was no less real, improbable or false, nor did I give any of them less intentionality or less of myself. I merely became practiced in the art of nearly. Anthropologists also, are very accomplished in the art of nearly. They learn the life ways of the other, they study language, culture, texts; written and spoken, sacred and profane. By observation, emersion and deep contemplation they dwell in otherness until otherness becomes them. Some dread leaving the field, having forged genuine ‘kin’—relationships borne of years of negotiated and shared meanings. Some ‘go native’ and stay in the field.

I believe I have led an intersubjective life where the meanings I have made of the work that I have done have as much to do with the people who inhabited the spaces, as I did with absorbing the culture I practiced. Intersubjectivity suggests they too, took something somehow useful from me, and together we built our time, our place, our culture.

I cannot call my way of going merely a series of anthropological projects. Not only because the projects lack some sort of a priori intent of being anthropological projects, but because I didn’t collect field notes, and record and analyse them back in my scientist lab. After all, this is the stuff of social science, the thing that would make my knowledge claims in each of the areas genuine and real—not fictive and emotional. But perhaps I can call the ways of being nearly...the intersubjective method or mode. The intersubjective method begins as genuine inquiry and ends as genuine kinship-like alignment.

In most traditional methods, such as case study, grounded theory, phenomenology, and even ethnography the powerful researcher is always fore grounded; at best removed, separate, observing, recording, describing, APART—at worst, omnipotent. The resultant texts are generally ‘analyses, syntheses and hypotheses’ about. Rarely are the texts, authors and objects inscribed compellingly meaningfully TOGETHER in pure narrative, film, virtual space or art.

Learning commercial innovation intersubjectively

An Intersubjective Method is one which powerfully incorporates a decentered subject, encourages emersion and uptake of culture without guilt in an ‘ethic of care’ sense, fosters genuine trust, relationships and mutuality. Gubrium and Holstein, in Interpretive Practice and Social Action, Chapter 19 of Denzin & Lincoln, note:

Individuals who interact with one another do so in an environment that is concurrently constructed and experienced in fundamentally the same terms by all parties, even while mistakes may be made in its particular apprehensions. Taking for granted that we intersubjectively share the same reality, we assume further that we
can understand each other in its terms. Intersubjectivity is thus a social accomplishment a set of understandings sustained in and through the shared assumptions of interaction and recurrently sustained in processes of typification. (Denzin & Lincoln, 2005, p. 485)

In my years of nearly being, I fostered many relationships in which both parties benefitted, but which I was clearly the noviate. I observed, memorised, patterned, befriended and became at first an apprentice and later, fully initiated part of the culture into which I immersed myself. My eventual distancing from many of these sites due to relocation or changed pathways did not involve an ethical dilemma or angst. Sadness and loss were much more commonly felt emotions. My time as a mother of three, my time as an academic, my time as a librarian all story my life like chapters in a book. In his book, Minima Ethnographica, Jackson highlights the place of immersion and intersubjectivity in everyday fieldwork and the role of story in ethnography:

In the course of doing fieldwork, an ethnographer hears and records a lot of stories. Conventionally, one converts these stories or fragments of stories into anthropological essays, dissertations, and monographs. It’s an academic habit that goes back to the early seventeenth century, when the rise of science entailed a dissociation of sensibilities” in which authority shifted from direct testimony and immediate experience to abstract and imperiously panoptic forms of discursive practice. (Jackson, 1998, p. 33)

When I consider the methodology I used in studying people I knew/know very well, I begin to think of an intersubjective methodology which includes:

Initial admitting of novice status and ‘apprentice’ position
Keen observation and attention to detail
Mimicry, including use of language & colloquial expressions
Building a repertoire of experiences so knowing-how, knowing-why claims are recognised
Fundamentally grounded with an ethic of care—i.e. “care and concern”
Lengthy period in the field

Writing in an intersubjective mode acknowledges multiple positions, multiple ways of knowing and commonly experienced mythos—play and work lives which reinforce and validate personal experiences. Mostly, an intersubjective method allows us to work very closely with populations known very well. So, rather than knowing “the other” we know “the us.” To illustrate the benefits of an intersubjective methodology, let me recall a story from my early graduate student days called “My students”: 
My Students

As a new PhD student, I attended a weekly seminar sponsored by our department, where all sorts of research topics were discussed—from methods to moments. At one stage, I recall a rather heated conversation we had with another PhD student. For seminar, we had read Brickhouse’s *Ethic of Care*. After this we had a small discussion about ethics in the research we were doing, and the sites at which we were undertaking the research. One teacher claimed it was ethical to use information from his primary school classes without expressed written permission because they were “his students” and he had “their best interests” at heart. In short, his philosophical position was that he was free to plunder the data that went on in his classroom because they were “his” data (even though they were little people who drove the observations which would become the data). Another classmate and I took umbrage at his point of view, saying it was unethical to observe, note and record data about them, even in his own journals, without permission from the parents. We argued, if his notes or texts were ever published, it might be possible that a child could be identified. This then opened up all sorts of additional ethical questions about non-explicit research by teachers. It became an ethical stalemate—he believing his role as teacher allowed him to do this (for heaven’s sakes he cared deeply for their better education!) and we believing he was no different than any other researcher coming into the classroom and he should be subject to those requirements. I think our moderator stopped the discussion before it became too heated. The summary comment was an understatement—“It is a very tricky situation.”

Of course, in the starry brilliance of fervent new PhD candidacy, I saw the teacher as being as culpable as Laud Humphreys and his unethical studies for *Tearoom Trade*, about which I must surely have just read. What I didn’t see then, but do now, with a bit more wisdom and personal experience, it that is very tricky. To turn the tables, what would the student who was involved in the above story think about my portrayal of him as a plunderer of data who may misrepresent his students? Of course one can, blinkers on, ignore issues like this as researchers, but addressing them head on with an attendant methodology might give more justice to the situations. Perhaps in this thesis I have misrepresented someone at the Company. If they knew I was to write about innovation and translational dialog in this way, perhaps they would have objected? In other words, was I to have gotten consent forms from each of my colleagues? Is this different because they are not children? If one accepts our lived situations – teacher, researcher, factory worker, church-goer, as intersubjective, where shared cognition and consensus is essential in the shaping of our ideas and relations, one can legitimately create story and restorying without ethical dilemma. This is exactly what Michael Jackson does in *Minima ethnographica*:

The focus on intersubjectivity helps us overcome the sterile, essentialising, either-or habit of categorizing experience in terms of purportedly substantial, immutable, and opposed states of being such as self versus other, local versus global, West versus East, North versus South. By shifting our focus to the mutable field of intersubjective experience, such antinomies come to be seen not as reflecting the world as it is unto itself but the world as we represent it to ourselves the better to inhabit it with some sense of knowledge and control. In these intersubjective fields identity and essence may provide a useful currency but they should never be allowed to possess absolute value. (Jackson, 1998, pp. 195-196)

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5 It should be noted that colleagues have read all material prior to publishing. The Company also sought my expertise in writing, rather than me parasitically plundering their innovative spaces, and writing them up for my own benefit.
Indeed, the intersubjective method so described in *Minima ethnographica*, which becomes my modus operandi for the exploration of my thesis questions, might provide an important referent for learning to be innovative at the graduate student level. Perhaps more important than any generic skills, a debate that continues to rage on in Australia for nearly a decade at the time of writing of this thesis, a concept of intersubjective learning in practice might be more beneficial in learning innovation than any lengthening of the degree program with additional coursework units. Models of internships, student teaching, etc are increasingly prevalent in undergraduate and graduate programs in medical sciences, social sciences, law, business, education, etc. Why leave engineers and scientists behind? If one is truly able to adopt an intersubjective modality one must move to understanding of self and others:

I belonged to a world where meta-narratives such as the moon story no longer bestowed legitimacy or justified actions. Nor did rules of scientific method, correspondence to the facts, and consensus within a professional or scientific community determine what was true and false. In a postpositivist, postmodern age such modes of determining ethnographic truth were under siege (Lytard 1984), and even the myths of humanism—that all men were created equal, or that resources should be distributed “from each according to his abilities, to each according to his needs”—were outrageous forms of wishful thinking when one considered the terrible history that colonized people had endured. But this is to see difference solely in epistemological terms. In fact, ethnographic understanding is a product of interaction and dialogue, and accordingly contains the possibility of going beyond the merely local or personal, to afford glimpses into a wider world of shared existential quandaries and imaginative strategies. (Jackson, 1998, p. 180)

I recall the words of a friend who uttered in despair “My PhD experience was the loneliest experience of my life.” I will echo those words. My PhD experience was lonely. Had it not been, I would not have learned how to teach myself what I do not know. The tenuous balance the Supervisor must tread to know exactly the right time and amount of care, concern and pressure is one that may be recognised, but may end in negativity or ill feelings if students are not able to discern the ultimate benefit of the most appropriate supervision. “Appropriate” is not the same for all students, as I noticed between, for example, Zahir and Brad. The true value of the PhD for me was to facilitate a rewarding career. When I commenced my study in 2003, I had no idea five years hence I would be involved deeply in transitioning myself from academia to industry. The point is that through the lonely searching days, I was able to find catch points—ways to bootstrap my knowledge when I knew very little about a project, plan or organisation. But I am not too different to other successful PhD students. The difference between me and my engineers is that I have bootstrapped a degree in engineering education, to work in a pre-dominantly male environment of the international oil and gas Industry. Lessons learned from the PhD were not only about manufacturing knowledge, but about being fleet of foot, tenacious and an effective project manager. I do not retain overall impressions of despair and loneliness, but skills-in being an *autonomous* thinker, planner, and skilful leader. As a final rejoinder about dwelling in and dwelling on, I review the contributions of the thesis:

1) **Voluntary Inattention**—I define the importance of adult play as evidence in working
groups of students and Company employees

2) **Graduate Engineering Knowledge Acquisition Model**—I discuss the process by which
graduate students must move through three Ecologies, the Network, the Social and
the Knowledge in order to prepare themselves for a career in industry or the academy

3) **Definition of graduate engineer innovation**—I define unequivocally that publishing in
discipline appropriate ways, the output of students is defined as innovation.
4) **Translational dialogue**—I define learning in industry where apprentices must have ready access to those with greater skill than themselves, where differences in design and fabrication are resolved by negotiation and accommodation where each party comes to a better understanding of the requirements of the other.

5) **Intersubjective method**—I suggest the promise of an intersubjective method as applied to educational research, where researchers resist temptations to: essentialise, to distance themselves from the field in order to get a better view, to write, as Jackson suggests ‘disassociated texts in cabalist language’.

**Final thoughts** In an early section, I established two distinct categories of criteria by which I wish the thesis to be judged. I finish the thesis with a refresher of these two quality criteria—Academic and Literary criteria. I ask the reader to utilise *Strength, Sharing and Service* from Mulholland and Wallace (Mulholland & Wallace, 2003), to assess the Academic quality of the thesis. For Mulholland and Wallace validity in qualitative research writing is verified by the following three criteria sets: Strength—A set of quality criteria that requires research to be conducted in ways that provide evidence of thoroughness and fairness; Sharing—A set that allows the reader to experience vicariously the world of the participants; Service—A set concerned with the ways in which education is enhanced for researcher, participants and reader (Mulholland & Wallace, 2003, p. 5). StRENGTH criteria relates to the way in which the research is carried out—length of time in the field, use of multiple data sources, documentation of researcher subjectivity, interpretations subject to outside audit, issues of voice, etc. These contribute to the strength of the knowledge claims’ (p. 8). The StRENGTH criteria was applied primarily in the second section II Context, where the details of the study, the literature, the methods, methodology and theoretical framework were discussed. The second criterion for academic quality assessment was the Sharing criterion, where ‘qualitative work is shared with others who, through reading, experience vicariously events and phenomena described’. The Sharing criterion was to be applied to the III Analysis section, which presents the stories of the Supervisor, students and laboratory. The aim of my study and the representations presented in the III Analysis section was ‘...to allow the reader, through the writer, to make contact with those who have been studied’ (Mulholland & Wallace, 2003, p. 8). The final criterion, Service, is the degree to which the study provides ‘a social experience in which the researcher assists others to construct knowledge by describing a case in such a way that the reader makes useful comparisons.’ (Mulholland & Wallace, 2003, p. 9) I attempted to satisfy the Service criterion in the IV Linkages, V Findings and VI Epilogue sections where I present a Graduate Engineer Knowledge Acquisition Model and derive a definition of innovation in graduate education by resolving the question of ‘how does the graduate student in engineering innovate?’ Here, a goal was to offer the reader some ideas for generalisability, some purchase for their own work, life, industry, perhaps via an intersubjective method as a way of ‘coming to knowing’ something, as I came to know commercial innovation.

To assess the Literary quality of the thesis, I ask the reader to be attuned to qualities espoused by Laurel Richardson. As much as possible, I have tried to incorporate literary qualities from Richardson, where:

The researcher’s self-knowledge and knowledge of the topic develop through experimentation with point of view, tone, texture, sequencing, metaphor, and so on. Another skill, another language—the student’s own—is added to the student’s repertoire. (Richardson, 2000, p. 936)

Richardson suggests a number of tools which engage narrative, which include mixed genres and polyvocality, observation & descriptive devices, organisation, pace, tone, & time.
In utilising these tools to write narrative, she had several standards by which she believes ethnographic description should be judged. Briefly, I shall summarise how Richardson (2000, p. 937) suggests assessment of Literary quality:

1) **Substantive contribution.** Does the piece contribute to an understanding of culture?

2) **Aesthetic merit.** Is the text satisfying, appropriately complex, with well executed, memorable characters?

3) **Reflexivity.** Does the reader get a sense of how the author gathered the information and wrote this text? Does the author clearly state their subjectivity?

4) **Impact.** How does the text make the reader feel? Does it answer some questions but spark others?

5) **Expression of reality.** Does this text embody a real, lived experience?

Richardson, like Jackson, strongly rejects the cabalistic, disciplined ethnographic inquiry; rather she espouses other sorts of ethnographic narrative arising from knowing the other. As such, I discuss Richardson’s Literary quality criteria as it relates to what I have offered the reader here. Do I make a **substantive contribution** to knowing graduate engineers in a laboratory, to knowing how they work?, why they work, what are their aspirations?, and most importantly, how they innovate? Moreover, do I contribute to the readers coming to knowing how innovation happens in the high powered oil & gas Industry in the USA? In short, does the reader know more than before about these cultures? If the answer to these questions is yes, then I have sufficed Richardson’s **substantive contribution** criterion. Next, do I offer the reader a corpus of work with **aesthetic merit**? Have I offered a montage of the Supervisor with enough complexity so that the reader might know such a person? Can the reader see the welder descending the manway into a dry habitat to weld on the pipeline? Can the reader see me in the laboratory, jotting notes, listening for conversations behind me, wondering about Cramer-Rao bounds? If the answers to these is yes, then I have sufficed Richardson’s **aesthetic merit** criterion. Have I been careful to alert the reader of my subjectivity, my intersubjectivity? If so, then this has sufficed Richardson’s **reflexivity** criterion. How does the reader feel about the characters in the thesis? Did they smile when reading that Dock was ‘optimising the solution’ to the water all over the floor? Or feel awkward when Marvan mentioned the required bribe to undertake his PhD in Australia? Does the reader want to know where all the students are now, some six years from the commencement of my research? Does the reader want to find Jackson’s book *Minima ethnographica* in order to know more about the intersubjective method of research, and perhaps try it? If the answer to but one question is yes, then I have succeeded in making an **impact** upon the reader. Finally, does the reader believe that I have provided a real experience—driven by inquiry but made real by deep, thick description? Have I answered all the questions one might have about research students in engineering, how they solve problems merely to solve them, how they (and I) manufacture knowledge and how we all muck around a little bit as **VOLUNTARY INATTENTION** – a diversionary tactic from the hard work of writing, solving, creating? Does the reader believe I lived and recorded each and every moment of this work? If so, then I have sufficed the **Expression of reality** criterion.

I believe I have sufficed both academic and literary criterion by telling the very best story I can of the engineers; those in the laboratory and the Company. I discussed both rewarding feelings and feelings of isolation, eureka! moments and moments of despair. To the best of my ability, I have produced a story of innovation; theirs, mine, ours. But there are voices who are not here included. The voice of the student who did not want to be a part of my study is still mute. My supervisors’ in thesis and in work, quietly supporting me, are but whispers of breezes filling my sails. My children’s caws of ‘when are you **EVER** going to finish
writing? circle round me, but cannot be heard. Proud parents wait patiently for their doctor. The reader does not know these stories. The reader has great privilege, but not the truth as all encompassing reality. *What is seen depends upon our angle of repose.*

The metaphor I chose for the thesis was a simple story with archetypal characters—Osebo, representing the Supervisor, Mmboro, representing the students, and Mmoatia—representing illusive innovation. I have played Ananse, the spider, gathering these treasures and I present them to you, the academy, now.

This is my story which I have related.

If it be sweet, or if it be not sweet, take some elsewhere,
and let some come back to me.
Appendices, Reference Lists, Acronyms,
Appendix 1  Chronology of lab observations, visits, interviews and events
# Chronology of lab observations, visits, interviews and events

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<td>19 November</td>
<td>Interview John</td>
<td>45 mins</td>
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<td>25 November 2003</td>
<td>Interview Marvan</td>
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<td>25 November 2003</td>
<td>Interview Dock</td>
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<td>20 January 2004</td>
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<td>15 December</td>
<td>Interview Saif</td>
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<td>17 December 2003</td>
<td>Interview Tom</td>
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<td>23 December 2003</td>
<td>Interview Yasir</td>
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<td>24 February 2004</td>
<td>Interview, Supervisor</td>
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<tr>
<td>23 April 2004</td>
<td>Interview, Innovator in Electrical Engineering (2009 ATSE Clunies Ross Award Recipient for Australian Innovation, Prof Zigmantas Budrikis)</td>
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<td>14 October 2004</td>
<td>Interview Tom</td>
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<td>November 2004</td>
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<td>November 2004</td>
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<td>December 2004</td>
<td>Interview Brad</td>
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<td>December 2004</td>
<td>Interview Goran</td>
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<td>December 2004</td>
<td>Interview Zahir</td>
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<td>April 2005</td>
<td>Interview Safwan</td>
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<td>Leave of Absence, 2006-2007</td>
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<td>August 2007-Present</td>
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<td>February 2008</td>
<td>Interview Todd</td>
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<td>January-February</td>
<td>Interview Lance</td>
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<td>March 2008</td>
<td>Interview Eric</td>
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<td>April 2009</td>
<td>Interview Adam</td>
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Appendix 2  Student interview questions
The following are discussion questions for ICT / Innovation graduate student interviews. The prompts are to be used when the student requires clarification or examples from me.

Tell me about your background…

1. Please describe who or what brought you to do a PhD (rather than ???)
2. Who/what inspires you?
   Prompts: search for knowledge, money, recognition, parents/family, societal pressure “getting a good job”

Tell me about your laboratory…

3. What distinguishes your laboratory from other labs working in the area?
4. Describe roles in the group—Prompts most senior, expert tutor, speaker or voice, organiser, experimentalist, software expert, hardware expert, designer

Tell me about your work…

5. Describe your thesis. Has this changed over time?
6. Describe your normal working week in terms of working hours. When is the lab most productive?
7. If prompting required…say “In your average day do you:”
   Prompts: Work on research?

   Assist other PhD students (informally)?
   Assist undergraduate students (informally)?
   Assist supervisor
   editing, reviewing, preparing grant applications
   or written material, preparing oral presentations?
   Formal (remunerated) lecturing, tutoring, labs/pracs, marking?
   Administration?
   Other?
8. What is most disappointing in your current work?
9. What is the most rewarding in your current work?
10. Do you prefer to work: in teams, alone, mixture, depends…? Please explain and give example(s).
11. Which of the following is more important to you? Why?
   a. To get it right  b. To get it done  c. To do it my way
12. How do you prefer your performance be judged? Why?
   a. By what you do  b. By how you do it
13. How does innovation happen?

Tell me about your future…

14. What is the most probable employment opportunity for you after you get your PhD?
15. What do you think is the most valuable skill you will bring to your chosen area of work?
16. Where do you hope to be in five years? In ten?
17. Do you think it is important where you got your degree from?
18. Which countries will you think of going to work?
19. Do you feel Australia offers you the full range of potential employment areas?

Tell me your opinion…

20. Describe, in general, your view of the position electrical/electronic engineering PhD students have in society.
21. Is this true in Australia?
22. In comparison to your country, does Australia have more or fewer student undertaking PhD’s in your area?
23. In industry, what do you think is the most important goal?
24. In academia, what do you think is the most important goal?
25. Would you recommend a PhD to your friends?
26. If you could go back to the beginning of your study, what would you do differently…why?

Prompts:
Not do a PhD
Undertake study in a different area
Take more units
Have industry secondment/work outside academia
Write more journal papers
More conference travel
Focus more on study
Do less
  Teaching
  Administration
  Socialising

Do more
  Teaching
  Administration
  Socialising

27. Given your goals, do you think the PhD could have prepared you better? Ie Would you take any industry secondment or business units?

Tell me how you do it…
I am very interested in the engineering design process. Please will you tell me your view of how engineering design works? What book is on your bedside table at the moment?
Appendix 3  Risotto an existential discussion on my BlackBerry
----- Original Message -----  
From: Tanya M Vernon  
Sent: 06/12/2009 06:01 PM CDT  
To: Bill G Smith /EMAIL@EMAIL@ONYX  
Subject: Re: Risotto  
All day I have thought about the words below... "...being with people who  
don't judge".  
There are so many we's that are one person...if one sees only two  
or three  
sides of a person, that cannot be the full picture. Judging is  
pointless, I feel.

----- Original Message -----  
From: Bill G Smith  
Sent: 06/12/2009 07:25 PM CDT  
To: Tanya M Vernon/EMAIL@EMAIL@ONYX  
Subject: Re: Risotto  
Interesting concept! Society still tends to view people on first  
impressions. I am a believer in peeling back the onion a layer at  
a  
time...you may be pleasantly surprised by what's inside?

----- Original Message -----  
From: Tanya M Vernon  
Sent: 06/12/2009 07:54 PM CDT  
To: Bill G Smith /EMAIL@EMAIL@ONYX  
Subject: Re: Risotto  
Yes.  
And who we are, of a moment, is that angle viewed by the someone  
who has  
more or less an impression...  
An angle which also changes as the layers are removed...

----- Original Message -----  
From: Bill G Smith  
Sent: 06/12/2009 08:58 PM CDT  
To: Tanya M Vernon/EMAIL@EMAIL@ONYX  
Subject: Re: Risotto  
Wow...heavy stuff...

----- Original Message -----  
From: Tanya M Vernon  
Sent: 06/12/2009 09:17 PM CDT  
To: Bill G Smith/EMAIL@EMAIL@ONYX  
Subject: Re: Risotto  
Heavy? Really???.

Who humans are is simply the sum of those angles of inclination &  
declination--which change as the players move & know about the  
galaxy,  
theirs \ yours..
Knowing then, is about location ... in reference to something. How can being NOT be in reference to other?

The e-mails one exchanges, do change the exchangers. Yes? Simple. Yes?

----- Original Message ----- 
From: Bill G Smith 
Sent: 06/12/2009 09:42 PM CDT 
To: Tanya M Vernon/EMAIL@EMAIL@ONYX 
Subject: Re: Risotto 

Very simple!
Appendix 4  Observation 17 of 34, 1 July 2003
Observation 17—1 July 2003

8.50 I arrive early today, and am quite surprised when I hear animated talking from the lab as I walk down the corridor. I hear, as I walk through the door “...well we better get the cake early then.” As I walk down the passage, the lively discussion stops...when I round the corner, Safwan is smiling happily and comes to me and puts his arms around me and hugs me. I thought it could be something about the wedding or??? Safwan happily reports...that he and Dock have had papers accepted at SSP. I congratulate both of them. They had just checked their e-mails and discovered that Prof Taza had sent an e-mail of congratulations to the entire lab <DEG>, of which I am a part.

Safwan announces he has other good news regarding the Visa. He reports that Delia has helped him a lot.

Safwan: She will send me a letter this week. And the IPRS is picking up the cost of the Visa renewal. I will only have to pay the cost of the medical exams...probably.

Dock and I tell Safwan that is really great.

Tanya: Will you present the papers? When is the conference?
Dock: Well that is another question.
Safwan: In 2004...I think.
Dock: No, it is this year. Look [indicates poster]. It is the 29th of September in St Louis—America.
Safwan: I would really like to go.
Tanya: Maybe you can combine it with your travel to Great Britain.
Dock: When is your Italy conference?
Safwan: The 14th or so of September. I am really excited. I have airpoints that will take me to Italy, so maybe America too? I don’t know if Prof Taza will approve.

OBS: I am concerned that I did not get the e-mail which the others got. I tell Dock and Safwan. Safwan checks the recipient list and notes I am still there. I begin to fret about this, as is usual, thinking I have been booted out of the lab.

I ask Dock about his recent move. He reported that it was completely done on Friday night.

Safwan calls me over to look at the recipient list.

I return to the conversation with Dock.
Tanya: So you finished on Friday. Did Safwan help you?
Dock: No
Safwan: I waited for him to call me, and he never did. On Saturday I called him to ask why he hadn’t called me!
Dock: My friend helped, and we finished at 2.00 am on Saturday. It was all done, and very little got wet, because we had the van.
Tanya: Great.
OBS:  *I wanted to ask him if all the unpacking got done, but:*

9.10  Marvan arrives.

Tanya, Dock & Safwan (in unison).  Hey! Its Marvan...welcome back!!!

Dock:  How was your trip?
Marvan:  Oh, it was great.  I learned to shoot a gun...I never shot before, but now I know.

Marvan describes how he learned to shoot.  Safwan disagreed with how to aim.  He set up the telephone book and told us that in the Army he was taught to shoot well below the target or bulls eye.  Marvan said this was incorrect because due to trajectory the bullet declines in its path.

OBS:  When Safwan and Marvan disagree, there is no end to the discussion.  I attempt some levity, in order to return the conversation to the focus of Marvan and his holiday.

Tanya:  Ok., but remember, Safwan is using Egyptian guns.

[Dock, Marvan and even Safwan laugh]

Safwan:  No, o.k, o.k.

9.12  Dock and Safwan leave to get cake.  Marvan and I speak a few more words about the holiday, especially about kangaroos to be used, which the sheep station owner uses for dog meat for the sheep dogs.  I ask Marvan if he would ever shoot anything.  He says he would shoot feral cats and rabbits, probably.  He continues to tell me about like on the station, and how, though it was not lambing season there were many lambs.  Also, how he and station owner discovered that a fence had broken and the rams got in with ewes.  He helped round all the sheep up (some 500!) and then began the sorting.  His face beams with the excitement of even the retelling of the tale.

9.30  Marvan departs to change.

9.37  Bishr arrives.

9.40  Dock and Safwan return.

Dock:  Hello Bishr.

9.41  I ask Dock if he got his LCD display.  He reports he has no money now.

[discussion of electronics]

Safwan states he got a new DVD player.  I thought this was unusual as he said he had fixed his old DVD player.

9.48  I tell everyone that my account has been deleted.  I look at Safwan and mention that it is the Department.  There is some discussion about when the cake will be eaten.
9.49 I go to get coffee.
9.49 Rajan sees me in the corridor.

Rajan: Hi Tanya
Tanya: Hi Rajan.
Rajan: I have that form to sign. Where is it...[looks]. Obs: this is the informed consent form for the study, consenting to my participant observation.

Tanya: Oh, thank you. That is great
Rajan: Ah, this is my last day...
Tanya: What? [surprised...I think he means last day of working there]
Rajan: No, that means last day for marking. Look, look at my bag. Terrible. Really, it is disappointing results.

Tanya: What year?
Rajan: All years, honours, pg’s. Really bad...[continues looking for form].
Ah, here it is...[he signs], asks me the date and dates the document.
Tanya: So when is the baby due?
Rajan: In 8 weeks. I have so much to do—with visa’s and immigration. I am not an Australian resident, but I am also not Singaporean. So much to do...[the phone rings].

I tell him about cake just before he picks up the telephone. I heat the kettle, but don’t make coffee.

9.55 Dock asks for my e-mail address. He then asks for Denise’s e-mail and then sends an e-mail (see attached). I don’t see the e-mail because I have no e-mail connection in the lab.

10.06- Go get coffee and return.
10.07- Bishr: [comes over] Congratulations Safwan & Dock. Safwan and Dock thank him, and he returns to his desk.

10.11 Dock puts his lunch in the fridge in the lab.
10.17 Safwan comes over to ask me about St Louis, where it is located in the US. I tell him. He wonders where Louisana and Florida and New York are. I remind him that the US is really big—slightly bigger than Australia.

10.18 Yasir arrives and puts things away.

10.19 Safwan calls me over to a map he has found on the www site. We locate all the states he is interested in.

10.27 Safwan: What time is it there?
Tanya: I don’t know, about 10-12 hours behind, I think. There are three time zones, like Australia, and so it depends.
Safwan goes to the telephone. He dials a lot of numbers.
Safwan: He speaks in Arabic then…”The American make you forget Australian?” Arabic...then “He hates us…” You guys are all getting married. I am the only one. I don’t get married. I don’t want. I am not going back to Egypt either. I stay in Australia. Really, really. I have good news. I have a paper accepted in Missouri. That’s good. I am not sure if I am coming. If I do, where? I need some accommodation—free food, free stuff. I am a poor man. <Arabic>.

I am just worried about accommodation...can you help me? I like to come of course. <Arabic> I don’t want to go back really. I am thinking to stay. <Arabic> anyway. ok, bye.

Safwan: He says he will help me if I do go there.
Tanya: Where is he.
Safwan: Kentucky.
Tanya That is a bit closer to St Louis...where in Kentucky?
Safwan: I will let you know.

OBS: Marvan had disappeared sometime during the conversation.

Safwan: Can I borrow your visa, Bishr?
Bishr: Yes.
Dock: How much does it cost?
Bishr: $123.00
Tanya: They are reducing the prices, on Monday I think.

Rajan: Where are you going? I was waiting for cake.
Tanya: When is cake?
Dock: This afternoon at 2.00.

Rajan: How are you Yasir?
Yasir O.K.

10.50
Safwan is searching google. Marvan is working on screen.

10.59 Safwan departs for his meeting with Subhash Mohnan.

I hear John speaking with HLH in the passage.

HLH “I need to get a few forms signed.
John I’ll be around until 2-3.00. Maybe I’ll leave at 3.00.
HLH I’ll catch you at 2.00 then.

11.05
John: Hi guys.

11.20
John: Congratulation Dock, good work [shakes hands]. Looks for Safwan—who is gone. Marvan—welcome back!!! Did you hire a car?
Marvan: Yes, but you know how they have a $2000.00 excess? And you can lower it to $300.00 if you pay $11.00 more? Well 11 x 10 is an extra $110, so I chanced it. I was really, really careful. Nothing happened the entire trip. Then, I was on the freeway to return the car, and this Mercedes came over into my lane. He was within a foot of me when I hit the horn. Then the guy pulled off.

John: He was probably on his mobile.
Marvan: Yeah, I just thought it was ironic because I had been really good and careful and within ½ hour of returning the car, I nearly wiped it.

John: Yeah, some of the drivers here. I was on the freeway the other day and this cab came across the lanes, he was so close to me that he left grill marks in my bumper.

11.30
John make mobile call—it is personal.

11.55 Marvan leaves.
11.59 Div returns, he is whistling.

12.07 John gets a mobile call. Again personal. “No, I am not ready to buy yet...I just need to know what we need to do to save up for it. We are not prepared for it straight away.

12.10 Saif arrives. I know this only by inference, as he does not greet anyone in the lab. John begins asking him a question about spread spectrum.

John: Sorry, I thought you had done that...

12.25 I wonder about lunch. I need to get something from the library.

Obs: Yasir did not appear to say something to Safwan and Dock. I wonder if there is a club within a club, and whether if Bishr and Yasir are on the ‘outskirts’ of the club.

During quiet times, I normally read. This time I am reading “Laboratory Life”, a book about a Salk lab in the 1970’s. Many of the issues inform what I am doing currently. In this instance the following seem salient questions to ask in interviews:

What texts do you use...what does your library look like? What does the lab library offer you?

What is the work space of each of the students. What is the realia they work with on a day to day basis?

For example, what does Dock’s classification scheme look like?

How do the students differentiate themselves.

I leave to get a sandwich at approx 12.30. As I am going to the Library, I decide to collect a book I had read at the beginning of the work associated with Dr Doug—The Soul of the New Machine.
At the library, there are two books on hold for me, so the process takes a bit longer than I expected. By the time I get to the lunch bar, the queue is really long. I am annoyed, and end up returning to the lab at approximately 1.00 pm. Dock is just beginning his lunch, as is Marvan. John is there, finishing a Coke. Safwan, Bishr, and Yasir are not in the lab.

1.10 Bishr and Yasir return, but eat at their desks.

During lunch with Marvan, Dock and John, we discuss TV antennas extensively. John’s does not work as well as he would like it. It needs another 10 feet probably, but this will cause more holes in the roof. The matter of reception is keenly discussed. Marvan has a brochure. Though he rents, he wants to put an antenna in the ceiling cavity. Both John and he agree that no-one will know. John says that there is so much current floating around that he shocked himself every time he touched it. As a boy he said he saw someone electrocuted in a caravan park while attempting to put up a TV antenna. He had dreams about that for years.

Safwan joins the group. He had a hard time getting something from Georges. Like me, he found there were many students around.

The conversation of the TV antenna is continued. They consider the shape of the UHF receptor. In traditional antennas, they are tube shaped, but in the hills version, they are ‘u’ shaped. John calls Yasir over to ask him. The response is not conclusive. John suggests that it could be method of manufacture that differentiates them from competitors, but serves no real function. Dock and John both suggest it could be a cost saving alternative.

I ask the guys about buying things at Tandy and Dick Smiths, etc. I say that in my experience, the people working there have very little true electronic knowledge. This was a very leading statement and stimulated conversation about that fact, and about computer stores. Marvan said that he had problems with computer stores, because they know the acronyms, but really don’t know what they are talking about. He has been looking for extra chips to upgrade the memory. He has been overclocking for ages, but needs to add actual memory. John responds:

John: How have you been overclocking?
Marvan: I go into bios and change the settings.
John: Ok. You can do that with the celeron processor.
Marvan: Yeah.
John: It is risky though. You are seriously at risk of compromising performance...
Marvan: Yeah, but I know what I need it for.

As an outsider, I make a judgement call as to whether I will query the term overclocking. I do so:

Tanya: Ok...what is overclocking?

John: You can overclock the CPU. You can make it perform better if you know what is happening. Most computers today say they perform at 240 Mhz. But this is only the
optimal performance, just when the CPU is warming up. After it has been on for maybe an hour, you won’t get that performance.

Marvan: Overclocking is a way to get all of the performance out of the chips. Say you have a Holden. You can, maybe, get it to go 200 kph. But, you can make that same Holden go 400 if you know what to do. Overclocking does just that.

I tell Safwan that HLH is here. He had already seen him.

We begin discussing Universities and their organisation. In Egypt they have Universities which have all disciplines, with the highest ‘cut-offs’ being engineering, architecture and medicine. The highest of all being electrical engineering.

Saif joins the group for approximately 5 minutes. During this, Safwan refers to the above being done the “...same why in your country.”

OBS: This was a good effort to bring Saif into the conversation.

I ask Dock how Universities in Vietnam are organised. He reports that each location has a different subject. Maybe there will be place of all engineers, then a different place for all scientists, those interested in medicine, etc. I mentioned that I thought this was a good way, because it would stop so much competition.

Saif does not stay long, and I see him over at Yasir’s desk (1.47).

Saif: “So the value of HI...if we have 1,2,3,5 then we take the minimum.”

I return to my desk at approximately 1.55. Dr HLH comes to see how I am doing in my PhD. I ask him my question about the constructivism unit. He gives me various points of view, and I understand his suggestions.

2.0- Cake is served. There are approximately 15 people there. I continue to discuss issues relating to the CRC. He tells me that a number of people from Cor-Tech have been let go. Two of them I knew, and one of them, I knew quite well. We agree that this is a shame. HLH says that the VC money would be stopped because there is no other money incoming. I tell him that Kevin is preserving the salaries of Matt Saunders and others. What I note, but do not say, is that he is preserving what is closer to him than his engineers, and those are his academics.

2.14- Saif and Yasir are the first to leave the celebration and return to their desks.

2.20 I return to my desk. I know that HLH will begin speaking with the students, and I will prepare myself for the discussion process.

There are multiple conversations. I see HLH speaking with Rajan, and John and Safwan speaking.

2.21 A mobile rings. It is Bishr’s. He picks up...speaks quietly.

2.25 Safwan is helping Saif. He explains it so that Saif appears to understand.
Session begins. However, HLH is not here, so I decide to go to the ladies room. When I return, HLH has only just sat down.

**OBS:** It should be noted that the most of the conversation was dominated by John. HLH has queries from time to time, and the observer does not catch all of the technical discussion. As much as discernable is included herein.

John I will start with the DSTO stuff. All of this relates to the B scan [explains a scan]. It relates to the pass of the GPR—the transmitter moving across the ground and collecting data. There were a number of passes of the GPR in different soils—some in dry sand, and in a mixture of clays native to South Australia where the tests were conducted. Also, measurements have something to do with the surface to air interface.

The various items have been buried and are called “STAP 1, 2, etc”. The GPR detects metallic & plastic both, since landmines could be of either construction. There are ambiguities due to whether or not the STAP is filled or not filled. There are resonance factors associated if the item (such as STAP 2—which is coke can) is filled. To sort this out, I take a background trace and a foreground trace.

HLH asks for clarification.

Yasir passes by with things from the tea, presumably to assist in clean up. Dock and Safwan also pass by, as does Raheem.

John hows HLH the traces he has plotted on paper. There are 2 dark lines—one positive and one negative. This is from the GPR samplings. The data will then be presented to the SVM.

John: The support vectors influence this directly[shows graph]...with non-linear decision boundaries. The variability of data will effect the generalisation of this line. The background sample is used....

I have set the non-tolerance for errors at 0. In this graph, all the points have been considered the SVM. Within that problem, and using the c (cost) value, there are a number of points which violate that margin. So if I allow for no errors...

John continues...

Door knock. Marvan answers & and returns and then leaves.

John: My problem is that it came up and different classify them. I kept doing it. I have tried so many times. So what I am thinking is wrong is that is has a massive amount of redundancy points. Probably I will have to re-represent the data. I will need to use the time-frequency or Wignerville.

HLH asks for further clarification.

You see, what it is doing is taking every point as a support vector—there seem to be no points which don’t violate that margin.
HLH: I seems like it could be cost problem—the cost function is set at no tolerance for errors. So if you put some weighting on it, it will change the SVM.

John: Yes, this could turn into a linear problem... it is called a linear SVM.

2.45 Yasir passes by, & returns at 2.47

2.46 Marvan returns.

John: The linear SVM seems to perform well. This is a linear programming problem and it is more adaptive.

John continues... more technical discussion.

Saif passes by, 3.03 returning at 3.05
I could put it into a SVM itself and then use a gaussian spreading function...
Then I will need to look at the wavelet packet decomposition and Wignerville.

Now... with respect to the literature [indicating three piles...] on the CDMA & SVM. This is adaptive process and there are three categories of how they approach it.

Firstly, let me tell you that are all using white gaussian noise. The first sort of literature deals with impulsive noise. The second is where they have specified the c parameter at .8. I am not sure why they did that and what is the role of the C parameter... nothing is explained.

HLH One needs to understand the role of the c parameter. How do you weight cost. It may be weighted more strongly.

John: This could be the solution to the CDMA problem.

HLH You should look at the empirical risk minimalisation. How did you do the optimisation?

John: In quadprog in MatLab. It does a fairly good job of it.

HLH: I need to look into quadprog.

John: I will need to re-represent the data, with the c parameter change. Show HLH an equation.

You see... the square root is inside the exponential.
HLH More like LaPlacian... OK, now the question is... what is the contribution?

John: Firstly to look into the C parameter and develop a kernal for the problem, and for the proper way of arrive in the kernal.

I have looked at the TFR representation. This is the orthogonal basis function.

Mobile ringing... John says it is his, but he keeps talking with HLH.
I was also looking at the wavelet packet idea. But the problem is with the mother
wavelet, and identifying which one gives the best data.

3.25 Safwan passes by.
3.28 Yasir passes by & returns at 3.33

HLH Slepiän is one of the greatest pieces of work with mathematics by an engineer.
Look at the summation of those orthogonal prolate functions.

Mobile goes again.

HLH: Well it was good you sort of worked that out...with the re-representation. Did
they really take 1,500 samples?

John: Yeah, but the thing is that some of the data appear inconsistent. In other words,
they say STAP 2 is there, but my data don’t find it.

Mobile goes again.

HLH There could be spurious data...to test you or just in there because they didn’t do
the measurement properly. You may have to be aware of that.

John: Yeah, better go. Thanks!

HLH jots some notes, as I do.

3.29 John departs.

HLH Safwan, are you free?

Safwan: Yeah, maybe...

HLH: Ok. Gabir was here about two weeks ago and he basically asked you to look at
what I asked you to do—look at non-integer values of chip duration.

Also, you were going to let me know why these peaks disappeared.

Safwan: Yeah, I figured it out. It was a Db scale in MUSIC.

HLH: Ok, so had to do with the Db scale. They normally plot it on a linear scale.
It is normalised—1 user with 4 delays.

HLH: What is the SNR (signal to noise ratio).

Safwan: Basically they take it from 0 to 10...mine is about 5 Db. [indicating
papers] This set shows the non-integer results.

There is something that interpolates the peaks. It is called FindMax function in
MATLAB.
HLH Why don’t you use Max, not FindMax.

Safwan: Discusses this and tells why. HLH is convinced.

HLH This only gives you the peaks, right? Assuming you can identify the peaks, how do you improve the RAKE receiver performance.

Safwan: [Discusses the paper he reviewed and how he used part of the ideas from that.]

HLH: You are limited by time steps.

Safwan: I am looking at the bit error rate performance.

HLH You have to look at it with and without it so you can recover some performance. The problem is estimating the channel parameters. If you have high delays, then it is harder to estimate channel delays.

Safwan: Do you think I should find the Kramer Rao bound.

HLH I think it certainly make it more scholarly.

Safwan: Yeah, o.k.

HLH Because BER = modulation format + SNR + a few others...

Safwan: The MAI is very small in the training sequence.

HLH What standard codes to you use.

Safwan: I used the Halamud sequence. It is a generic code. It is fixed.

HLH Halamud...is it standard for 3G?

Safwan: Yeah, it is standard across. By the way, I just wanted to say that I was not prepared very well for the presentation.

HLH You better get yourself sorted. You were under prepared for the presentation at the ATcrc, too. You can’t present stuff straight off the press. It is too fresh. You have to give it some time. You have to look at previous work.

Safwan: I get worried. I don’t like the last presentation.

HLH; Gives the story of the third dimension proof. A prize has been offered. But there are conditions. It has to be published..., it has to stand the test of time and be held to the scrutiny of the scientific world, and after 20 months, the prize of $1 million will be given.

You see at the reviews, the need to know how your work is progressing, how tell you are going, and how the CRC is helping you.
Now...you will need to test your method. If it doesn’t work, then you will have to find a new method...o.k.

Safwan: Yes, thanks.

4.00 Safwan departs.

I clarify with HLH. I suggest that Safwan did not hear what HLH said about the review, that he was already going on to the next thing. HLH does not think that was the case. I tell him I wondered why Safwan did not query when the next review was.

NOTE: I am concerned because I know Safwan will be away in December, but I do not let on with HLH.

HLH goes to get Dock. I apologise that I cannot stay longer. Dock and HLH go off to the seminar room.

Dock: You were not here last week. Were you sick?

HLH: No, I was tied up...
[conversation fades...]

If I can hear the conversation in the seminar room, I am concerned that Safwan heard my rather negative assessment of his personality to HLH.

Tanya: Safwan. Thanks for the cake!

Safwan: You are welcome. [Walking to me]. He is good...but the sequence is standard. I don’t know why he asks about this.

Tanya: Was it Hallamud? or what?
Safwan: HadSafwand. But really, this is standard stuff...he needs to do a bit of catching up in reading and things.
Tanya: Yeah?
Safwan: Yeah, but he is really good, really helpful. I think he is o.k.
Tanya: Good.

Note: Though Safwan did tell me, I did not write down the word HadSafwand. No matter what I did, I could not find it on the www. So I sent Safwan an e-mail to clarify.

4.30 Begin to pack my things, I depart, 4.40.
Appendix 5 Interview, Mark, December 2004
Student Interview, Mark

December 2004

Tanya: So, if you could tell me who or what brought you to doing a PhD?

Mark: Uhm, basically I looked at opportunities for work first, at first I thought I would rather work first and do something more practical, and then sort of looking around, there weren’t that many opportunities to work as a researcher engineer, which is what I wanted to do, so and then, I thought, ok, I will apply for the APA, and if I get that I think it would be interesting. Partly I had I had a discussion with Prof Taza, who was my engineering project supervisor and he partly convinced me by telling me what was to be gained, in his view, by doing a PhD.

Tanya: And you definitely found that happen? You haven’t regretted that decision?

Mark: No [pause].

Tanya: I know you just discussed it with me [referring to the ‘warm-up’ prior to the tape on], but how has your work gone in the last year?

Mark: The last year has gone ok in the sense that what I have, I’ve done some new things which have been accepted for publication, and uh, I have done uh also a lot of teaching so that took some time, some other things, but overall, its ok, I mean I am moving forward, which is the important thing. I am not in the same place as I was one year ago.

Tanya: So how does the lab here, or the group here function, and is that different from how it functions in Australia?

Mark: Yes it is different because here we are not Phd, students, and we are not sort of students working towards a PhD, and sort of taking on teaching as we wanted as a part time job. We are employed as teaching assistants with a salary, by the state and we’re allowed to work on our PhD for our own benefit sort of thing, so it’s, the mentality is a little bit changed. So obviously you feel a bit more obliged to focus more on the administrative things that need to be done when they need to be done because that is what you are getting paid for. So you have to sort of put your studies sort of aside a lot more and fulfill the obligations, in that sense. When something needs to be done administratively, or with teaching…

Tanya: So the priorities have shifted?

Mark: Exactly.

Tanya: For example, I know this party today took up quite a lot of time, so can you comment on that.

Mark: To be honest, the Christmas party for me, probably took up at most one day full work. But I was actually sick the week before the Christmas party so, I wasn’t involved
in some of the other stuff that had to be done beforehand. It wasn’t overall a big, a big thing, I mean partly because I was sick, but....

Tanya: ok. I noticed in the DEG group that certain people have certain traits or qualities uhm like uh, Tom knows more about coding and Safwan seems to uhm do a lot of teaching and that sort of thing, did you notice a sort of division of labor that goes like that? Different people having different areas...

Mark: I definitely think that the Professor picks up on that and certainly assigns tasks based on that.

Tanya: Like you yourself have web work?

Mark: Yeah not only that he, he asks to do art work for the group type thing, like when we had big group poster, outlining our research goals, and who all the people in the group are and I did that and these banners that are across the door in the hallways that and yeah, so when it came around, that was by default given to me and the web, sort of side of things, yeah.

Tanya: What about technical areas? As expertise, like would you be recognised for...know heaps about...uhm...array processing??

Mark: I guess, I don’t know what you mean, in terms of assigned tasks. Myself and Zahir are both the two people who are working in array processing. I guess if there was some technical work outside of our PhD, that was to do with array processing, we would probably be the people who would be the most logical to be working on that, I guess. My specific area of time frequency analysis is also not really done much by other people in the group. But, I don’t know...we are not really assigned technical tasks outside of our PhD work, that often. Although, I guess for Zahir…it is a bigger scope

Tanya: I know from the DEG group and from my long observations there, like if people wanted to do something, if they wanted to know about things administratively, they went to John Franks cause he seemed to know a lot about administratively. Especially like how you usher in a new person in the group, like, for example, Saif would ask Safwan. Then when he annoyed Safwan, then he would ask Yasir. Just in terms of how you would usher a new person in, like...

Mark: I guess it is a personal thing...like you would have a lot of discussions with them and talk about what you have done and what they are doing and whether it seems similar. My topic is a bit more individual, I guess, I mean compared to others, I mean I know that in Perth there was sort of four or five people all working on communications, and so all the guys, their topics were related. My topic really stands alone, I discuss a lot of things with Zahir, but he is also at the same level as me in terms of his work, he is not like a new student coming in...so. Like, I guess we don’t have new students coming in working in my topic, which means that...I don’t really have that much to say.

Tanya: Ok So would you go to anyone here in the British group for any sort of technical advise, or anything or are you past their expertise?
Mark: No, I mean there are people in the group who definitely know more about a lot of topics than I do. For example Goran knows a lot about statistics and uh, and so when I have statistical questions, I sometimes ask him or ask him if he knows of other references on the topic. Obviously he has been working a lot longer in the area, has a lot of expertise. And sometimes I discuss ideas with Zahir, at least he is in a similar area, so he understands the work, the concepts and talk about some ideas and what is possible, and whether this problems seems reasonable or you know when you get stuck on something, or whether it is just something that has been overlooked or someone offers a new perspective, who works in the same area.

Tanya: So it would depend upon how much of the literature they read, in terms of your need to speak to them?

Mark: yeah, I uh mean. While, well if someone else has more knowledge working in that area, partly by reading the literature, and partly by doing their own research, then, of course they are like a resource as well, like the library. If someone else knows something, the quickest way is to get an answer is by directly asking someone rather than searching indirectly through papers and books and stuff.

Tanya: To change gears a little bit, describe to me briefly your relationship with your supervisor.

Mark: Uhm, well my supervisor, sort of tends to uhm, uh, tends to give comments once you done something. So it is very, uh, fairly autonomous in terms of research. You, he suggests a certain topic for example, and you look into that, and you see what you can do. Once you have actually done something, you can show it to him and say “well, what do you think”. Is this worth publishing, or is it worth looking further into, and he’ll give his opinion and discuss the topic. But he doesn’t sort of along the way, say, work on this or work on that. I mean in my case, anyway, I don’t know obviously how he is with everyone, but it is a more like, kind of , you do something, and you don’t really go to him unless you have something to show him, in terms of like discussing research.

Tanya: So has it changed over time?

Mark: [clears his throat] Not really, although at the start, uhm I definitely discussed a bit more with him prior to writing the very first paper that I wrote. Uhm I would say I discussed more of the basic idea before I went through with rest of the work. Probably since that time, its been more once you have done something, then you go and discuss it with him. Probably...what can I do, yeah.

Tanya: So, uh, over the last year, has the thrust and focus of your thesis, has that actually changed?

Mark: The main direction hasn’t changed, but the concept has been quite refined, basically to the point of knowing what it should look like at the end, and having to work on certain things that fill out the chapters or to finish, to write some chapters. I mean to know which chapters need to be, work needs to be done for those sort of those, which ones basically what has been done and need to just fill them out, and basically the whole concept has been defined and...clarified.
Tanya: So what is the most disappointing thing about your current work?

Mark: Uh…[pause] …probably that I would like to have some real data to apply my theory. It is not easy to get, so. I have had a little bit of real data, but it was uhm, it was, it turned out to be something which was like basically, the data was so good, it was like synthetic data, so it wasn’t really…didn’t require much challenging, sort of, any kind of challenging work to, to extract information from it. What it would be nice to have some kind of real data where this kind of processing that I am working with is really required, and then I can really see whether it would work in practice or whether, you know, it is totally theoretical, its values…I mean…on and abstract kind of level.

Tanya: Ok. So what is the most rewarding then?

Mark: Uhm, [pause] it is always rewarding to get a paper accepted and to have some kind of feedback and confirmation that your ideas that you are working on are relevant or worthwhile to other people, of interest to other people, so mainly the feedback that comes from publications, because that is like a milestone, that is how you say you have completed something or you…it is not really anything until you write it down, if you know what I mean.

Tanya: I know exactly what you mean!

Mark: If you do write it down, and someone says, that seems good, reasonable, interesting, then that’s the reward for the work that…[can’t hear]

Tanya: Ok. I have a graph here that I uhm, I will turn the machine off in a minute, what I want you to do is this is 100% is to mark the percent of time that you spent on the areas there.

Mark: In the three areas, or individual…?

Tanya: You can do it however you like, I am not prescriptive. [completes graph] In terms of this graph is completed for me, how much influence in each of the areas have you had from your supervisor. Starting with planning…and just verbally.

Mark: Well in terms of planning, my supervisor suggested to me specifically a topic to begin research in, uh, or a research area and in terms of research scope, only very generally defined, I mean it wasn’t known exactly were the research would go when we started, until we started to getting some results, uhm. Uh, in terms of problem solving, uhm, I don’t go to my supervisor that often with specific problems, I talk more to, to colleagues and stuff, uh, but in terms of monitoring, he obviously, I have interaction with him whenever I get to a certain point that I am ready to publish something or sometimes to begin working on a new idea. I discuss it with him, the direction it should take. But problems within that, normally I discuss it with other colleagues, and in terms of the administrative side, well writing, he looks at what I write and gives me feedback on that. The teaching is, well obviously I give tutorials that follow his lectures, but I don’t really that much interaction with him. It is much more, we know what the tutorials are and he knows what his lectures are, and it is where you decide at the start that they follow a course outline, so I don’t really even need to think too much about the teaching, until it comes time to the exam and the assessment of the students and
interacting and networking is indirectly through the supervisor when he invites people to discuss research topics uhm, I guess that is researching?

Tanya: Ok, so if I am reading your graph correctly, 50% is on the area indicated here…

Mark: Administration & teaching…yeah.

Tanya: And then of the remaining 50% of the time, 70%…

Mark: No that is 10…

Tanya: Oh! That is 10! Ok, now that makes sense…that is great. Thanks. I am going to ask you a question now. Which is more important to you to get it right, to get it done, or to do it your way?

Mark: Uhm.[long pause]. I wouldn’t say that…I would say to get it right AND to get it done, like are equally important. Firstly, you try to get it right [laughs], and then you try to get it done. And usually that doesn’t happen [laughs] unless I do it my way. That is the answer to your question. Did you want me to say one?

Tanya: Uh like if you had, like…

Mark: If I had to say one, more than any other, uh, it is to get it done. I always say that, because you assume you are doing it correctly, you don’t…

Tanya: You wouldn’t keep doing it otherwise…

Mark: Yeah, exactly [laughs].

Tanya; Ok, so how do you think innovation happens?

Mark: Uhm, well in our kind of research it seems to be most of the time, in the theoretical side, kind of small, what would you say, epsilon contributions. So you take what someone else has done and you extend it by a small amount, which is somehow significant enough for other people to say, to be able to then say, ok, that is something interesting and can extend it another small amount. But it terms of big, sort of innovation, that comes, is driven by industry. You can think of any theoretical topic you want, but until someone from industry says “you know we have this problem and we don’t know how to solve it with our current methods”…then you don’t see like a huge focus and a lot of people working on that topic and trying to find where the theory fits in this area and try to come up with new ideas, new algorithms. It seems to be fairly driven by some kind of industry. I mean, that is engineering. It is not pure mathematics.

Tanya: Good, so after you finish your PhD, what is the most probable hum, place you will be employed or kind of employment you will have?

Mark: Uh, well there is two main options. One is academia, and the other one is industry. Personally, I am hoping towards the industry. Cause academia will probably be later after I have some more practical experience in industry.
Tanya: What industry specifically.

Mark: Any industry which makes use of signal processing. It is quite a broad range of possibilities, telecommunications industry, there is the car industry, there is almost any big industry which requires engineering will require signal processing so it is very open, the possibilities.

Tanya: Has that changed at all since you began your PhD.

Mark: Uhm, not really. I probably decided more firmly that I needed to get practical experienced if I was to come back at all to academia. Uhm, but then Great Britain has certainly given me more perspective on what is available in industry. In Australia it seems a bit bleak, how you know you can’t see the real opportunities of working with a Phd in industry, but once you get here, there is a bit more…there is so much more secondary industry here, it actually lives on the secondary industry, whereas Australia lives on the primary industry.

Tanya: What is the most valuable skill that you got from your PhD that you will take to your chosen area of work?

Mark: Knowing how to teach myself what I don’t know.

Tanya: Ok So where do you hope to be in 5 years?

Mark: Uh working in industry.

Tanya: And in 10 years.

Mark: Probably still in industry, hopefully. Uhm…in a, closer to a management role.

Tanya: So this goes back to what you just said a minute ago… but it is one of my questions. Do you feel Australia offers the full range of potential employment.

Mark: Probably not.

Tanya: Can you give an example where it is particularly limited?

Mark: I think Australia has a bit of everything…like there is a possibility to do a bit of every little thing, it is just that the actual size of the industry is not that big, so the physical number of positions available are so small compared to…even compared to the smaller population in Australia. So it is just your chances of getting the type of position you want, say to do research in industry is much smaller just cause there is a smaller number of those positions in Australia. But in terms of the spectrum, Australia seems to have a bit of everything.

Tanya: Much lower changes of getting a little bit for you.

Mark: Exactly.

Tanya: So there are only about 5 questions left…[Markoughs]. Could you define engineering for me please?
Mark: Solving real world problems. Applying mathematical or scientific knowledge to satisfy the needs of society.

Tanya: So in industry what do you think is the most important goal?

Mark: Well, in practice, from a company’s perspective the most important goal is to make money, from a, probably more from a government institution is to provide some kind of social service, infrastructure that would benefit society.

Tanya: So in academia, what do you think is the most important goal?

Mark: Uh, to teach, uhm people engineering skills, and to come up with new results in research areas which uhm can hopefully be beneficial maybe in the future to industry and technology.

Tanya: So would you recommend a PhD to your friends or brother or?

Mark: I would depend on their personality. I would only recommend it if they were uhm someone who doesn’t mind taking their time and is not in a hurry to get specifically to a higher salary and something like that because, if you are in a rush to do it, I guess you tend to focus more on getting it done, rather than doing it properly, so that defeats the purpose of it. Yeah, it depends on their personality.

Tanya: If you could go back to the beginning of your PhD, which was March of 2001, would you do anything differently?

Mark: Well, if I knew then what I know now [laughs], I would probably do EVERYTHING differently, but [laughs], uhm. It is difficult to say. I would obviously try to focus on my research maybe a bit more than I have done, but when I sort of think back over what I had to do that wasn’t research, it is a bit hard to avoid it. I mean there were things, you know, administrative things and teaching things or whatever that had to be done, and it had to be, so I mean the main thing, would to be focus a bit more on the research, but to some degree, it wasn’t really possible.

Tanya: K. Uhm, given your goals, do you think that the PhD could have prepared you better, I mean would you have liked to have spent maybe some time in industry? Or business units or marketing units or?

Mark: Uhm. [long pause]. Hmm. To prepare me to go into industry, probably some sort of industry experience, not working there, but working on a project required by industry would be helpful, but I think. In terms of the PhD, it is not really evolved, it is not really the goal to solve a specific commercial problem. It is to learn how to learn and to how to improve on previous knowledge and how to add something to general basic knowledge. So I think the goal is a bit different to working in industry, and I personally don’t think experience should be built into the PhD. I would personally rather wait until the PhD is finished.

Tanya: Switches off recorder for last question.
Appendix 6  Supervisor interview questions
Question set--supervisor

1. Please give me a bit of background on the students you have supervised.
2. Please tell me your philosophy of student supervision.
3. Where are your students employed? Is this your expectation? Have you had feedback from your students.
4. What are the benefits to you for supervision?
5. Please give me an example of the most disappointing aspect of your supervisor career.
6. Please let me know the most rewarding aspect of your supervision.
7. In terms of writing papers, please model the process you expect your students to undertake.
8. In terms of the supervision of students what is the optimal level (hours per week) which you have found to be most successful.
9. In terms of leaving students (for long service leave, study leave, or moving to another country), what do you expect students go through in terms of their behaviour. Give examples…
10. What are three key things you want students of yours to walk away with?
11. Do you feel students should add further skills to their capabilities?
12. How do you add value to the students’ capability profile (skill set)?
13. What do you think the research degree trains for?…is this true in Australia?
14. What do you feel is innovation in research training?
15. Do you feel students should spend some time lecturing? In industry?
16. Do you look for something in students which you sometimes do or don’t find?
Appendix 7 Personify me
Personify me

Login to me, Username:

Ego

Password: [case sensitive]

MY bitch

Am I your laptop | box?

Useful tool, smart and shiny

fuck

Remark me out tonight, lines of code

recite

or Click me open, icon

object

Erase me, delete my files

trash.

But one day, I shall be

velveteen

tomorrow, someone will love me

Real.

Written 17 July, 2009, 9.00 pm, rm 226, 11th floor Ontario Institute for Studies in Education, Toronto, Canada
Reference List


Prime Minister’s Science Engineering and Innovation Council. (1998). *University-industry linked research in Australia* (Minutes of a Meeting). Canberra, ACT: PMSEIC.


Tanya M. Vernon Publications List


**Acronyms, Definitions, Glossary**

_A story, a story_ title of book by Gail Haley, used as metaphor for PhD learning journey
Ananse = Spider Man, collector of stories
Archetype literary device defined on cover
Archives of Engineering pseudonym for journal in engineering which may identify the group.
Autoethnography is a form of autobiographical personal narrative that explores the writer's experience of life.
Blog short for Weblog
Calabash gourd
CDMA Code division multiple access. CDMA employs spread-spectrum technology and a special coding scheme (where each transmitter is assigned a code) to allow multiple users to be multiplexed over the same physical channel.
Confined Space A confined space is any space: 1) that has limited or restricted means of entry or exit; 2) is large enough for a person to enter to perform tasks; 3) and is not designed or configured for continuous occupancy.
CPU Central Processing Unit
Cramer-Rao Bound In estimation theory and statistics, the Cramér–Rao bound (CRB) or Cramér–Rao lower bound (CRLB), named in honor of Harald Cramér and Calyampudi Radhakrishna Rao who were among the first to derive it, expresses a lower bound on the variance of estimators of a deterministic parameter.
MATLAB software package used for data modeling, complex matrices, and graphical elements
Metanarrative A story about story. This thesis is a metanarrative, as is Peter Carey’s novel Illywacker.
Mmoatia the fairy whom men never see, archetype of innovation
Moment any point of occurrence of events, always in relation to other concurrent events.
Montage series of short video clips
Mumboro the hornets who sting like fire, archetype of the students
Nvivo software used to analyse quantitative data
Nyame = Sky God in A story, a story
Osebo the leopard of the terrible teeth, archetype of the Supervisor
Overclocking is the process of running a computer component at a higher clock rate (more clock cycles per second) than it was designed for or was specified by the manufacturer, usually practiced by enthusiasts seeking an increase in the performance of their computers
PLIDCO The Pipeline Development Company, a trademark for sleeves used in oil and gas pipeline repairs
RAKE Receiver is a radio receiver designed to counter the effects of multipath fading. It does this by using several "sub-receivers" called fingers, that is, several correlators each assigned to a different multipath component.
SPSS Trademark for Statistical package to analyse quantitative data
SVM Support vector machine algorithm that learns sequences in order to assign labels to objects.

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6 Definitions from Wikipedia.