Student Experiences of Problem-Based Learning in Engineering: Learning Cultures of PBL Teams

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Submitted by

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Abstract:

This study investigates the experiences of first year engineering students to a newly implemented engineering problem-based learning (PBL) curriculum at Victoria University; its effects on their approaches to learning and their learning outcomes. This qualitative study, which uses ethnographic approaches for data collection and analysis, focuses on the learning cultures that emerge in multicultural PBL teams by interpreting the responses of students to the new emphasis on autonomous learning.

In the first year of the curriculum change in this PBL setting, this research captures and theorises student approaches to learning as a team and their learning outcomes by analysing the ways in which these students approach and direct their learning as individuals and as a team. This area has received little attention in engineering PBL curriculum research and has been overlooked in most PBL literature.

It was found that student learning in PBL teams in this setting was mainly influenced by the attitudes, behaviour and learning approaches of the student members in that team. Other factors such as teacher practices, location, course design and implementation, resources, expected outcomes and the assessment methods also exerted influence on what and how students learnt through PBL. Three different learning cultures that emerged from the analysis of eight teams are reported in this dissertation. They are the finishing culture, the performing culture and the collaborative learning culture. It was found that students who used deep learning approaches demonstrated disciplinary and cross-disciplinary knowledge and skills. It was also found that teams that used a collaborative learning culture demonstrated innovative thinking to some extent although it was not an expected learning outcome in the course documentation.

The findings of this study imply that students in a problem-based, or project-based, learning setting may not automatically approach learning at a deep level. Furthermore, student teams may not adopt a collaborative learning culture. Hence, it is important for institutions and teachers to identify and consider the factors that may influence student learning in their particular PBL setting and to provide the necessary tools and ongoing coaching that will help students use deep learning approaches in a team and encourage student teams to adopt a collaborative learning culture.

Declaration:

I, Siva Krishnan, declare that the PhD thesis entitled "Student Experiences of Problem-Based Learning in Engineering: Learning Cultures of PBL Teams" is no more than 100,000 words in length including quotes and exclusive of tables, figures, appendices, bibliography, references and footnotes. This thesis contains no material that has been submitted previously, in whole or in part, for the award of any other academic degree or diploma. Except where otherwise indicated, this thesis is my own work.

Signature [redacted] **Date** 15th Dec 2008

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I wish to dedicate this thesis to my father S. Krishnan, my mother Seetha Krishnan and to the memory of my pet dog Aju.

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Chapter 1

Introduction

Undergraduate engineering courses in Australian universities have relied mainly on lecture-based teaching, supplemented, where appropriate, with laboratory practicals, tutorials, seminars, projects and other approaches peculiar to the discipline (Lloyd, 2001; Lloyd, Rice, Ferguson, & Palmer, 2001). Such approaches are inclined to be teacher-centred rather than learner-centred, with most of the responsibility for the content and structure resting with the teaching staff.

Teacher-centred approaches often assume that only the teacher contributes knowledge to the teaching and learning process. By empowering students as autonomous learners, it is possible to extend their role in the learning process in a range of ways from the shaping of investigations, through consolidating the learning of their peers to the development of learning resources (Ramsden, 2003).

From the mid 1980s learner-centred approaches to teaching at university have been widely supported by constructivist authors. They argued that teacher-centred approaches should give way to more interactive, problem-based and independent approaches and methods that support students while they tackle difficult problems and assume personal responsibility for their learning (Boud, 1985; Hadgraft, 1993b; Kolmos, 1996; Kolmos, Fink, & Krogh, 2004; Savin-Baden, 2000; D. Woods, 1985).

Problem-based learning (PBL) is an example of a learner-centred approach to teaching that has been used in health professional education settings for many years. McMaster University at Hamilton in Canada pioneered and extensively used PBL in its medical school. In Australia, the pioneers of PBL were The University of Newcastle Medical School, New South Wales College of Law and Hawkesbury Agricultural College.

Within engineering settings, Aalborg University in Denmark developed the Aalborg PBL model and used it extensively in their engineering degree courses. In Australia, the need to redesign engineering programs was identified following a review of engineering education. This review identified shortcomings such as inadequate attention to the professional formation of students, curriculum fragmentation and overcrowding, insufficient opportunities to cross traditional disciplinary boundaries and lack of responsiveness to changing external demands (P. Johnson, 1996). One response to this at both Central Queensland University and University of Technology Sydney was to pioneer the use of PBL in their engineering degree courses.

Because the PBL approach had mainly been used in health professional education, its introduction in engineering courses triggered questions about the suitability of the approach in engineering (Mills & Treagust, 2003). Research in engineering education since then has focussed on the design and implementation of PBL curricula, the advantages and disadvantages of PBL, the nature of student learning in PBL and the effectiveness of different teaching-learning approaches (N. J. Entwistle, 2005; N. J. Entwistle & Ramsden, 1983).

Most previous research into the use of PBL in engineering has been quantitative in nature and has mostly focussed on design, implementation and assessment methods (Newman, 2005). Although it has been claimed that PBL produces engineers with technical knowledge, cross-disciplinary knowledge and generic skills such as innovative thinking and team working skills, research on the ways in which engineering students approach, and direct their learning in a PBL setting is limited. This is the main focus of this study. The study attempts to investigate how students experience PBL and what they learn through PBL by investigating their approaches to learning as individuals and as a team.

This chapter is divided into two sections. In the first section the context of this study is outlined. This section also contains a brief overview of the literature about problem-based learning. The second section states the general aims of this study and provides an outline of this dissertation.

1.1 Context to the study

It is argued that PBL encourages students to learn actively as they adapt to change, solve problems in unfamiliar situations, reason critically and creatively, use a holistic approach, collaborate productively in teams, identify their own strengths and weaknesses and commit themselves to lifelong learning (Barrows & Tamblyn, 1980; Dunlap, 2005; Hmelo-Silver, 2004; Savin-Baden, 2000, 2003).

However, what students learn and how they learn it are influenced by many factors. Biggs and Moore (1993) described in their 3P model that student characteristics, teaching context, teaching and learning processes and desired learning outcomes influence student learning. Some of the student characteristics include their socio economic backgrounds, gender, ethnicity, social, family and work life, and opportunities for prospective employment in the area of interest. Apart from these, their attitudes, behaviour and preferred learning approaches influence how they learn in classrooms.

The teaching context also exerts influence on what students learn. This includes teacher characteristics, curriculum and teaching methods (Biggs & Moore, 1993). Other management level variables such as institutional policies and government policies and funding exert a strong influence. These in turn influence the wider academic and social values shared by the academic institution.

Biggs and Moore (1993) noted that the teaching and learning processes and desired learning outcomes directly influence the learning approaches of students. However, Savin-Baden and Major (2004) argued that the assessment system also exerts influence on what students learn in addition to all of these factors that affect how students respond to learning in higher education.

Marton and Säljö (1976) revealed that students approach learning in different ways and argued that the approach used was situationally determined. They identified two distinctive approaches students adopted when they learnt from texts and classified these approaches as the surface approach and the deep approach. Similarly, Pask (1976) distinguished students' learning strategies as holist, serialist and versatile according to the way they handled tasks. In contrast to this notion of learning approaches being situationally-determined, Perry (1970) identified a developmental sequence of nine positions through which students appeared to progress as they moved through college. The sequence involved development from a dualistic, authority-accepting position through a relativistic "anything goes" phase to a final stage of open-minded commitment.

While Marton and Säljö (1976), Pask (1976) and Perry (1970) used the processes students adopted when they participated in learning activities to determine their approaches to learning, Entwistle (1978) also studied their personal characteristics. He suggested that students achieve success in different ways with combinations of aptitudes, attitudes and personality traits.

Biggs (1987) initially suggested that student learning approaches may be habitual but later modified this to suggest that they are determined by the learning situation. He identified three approaches to learning; surface, deep and achieving approaches, each with a corresponding motive and strategy. He suggested that by using PBL it is possible to encourage students to adopt a deep approach to learning.

During the mid 1980s, the claimed advantages of PBL were seen to be particularly relevant to professional and vocational education, where educators started to acknowledge that the process of educating was more than transmitting knowledge. This led to some important research during the mid and late 1990s about the effectiveness of the use of PBL in higher education degree courses in Australia (Aldred, 1997; Bridges, 1992; Conway, 1997; Delisle, 1997; Engel, 1991; Kingsland & Ostwald, 1994; Ostwald, Little, & Ryan, 1995; D. R. Woods, 1996).

There is a considerable literature on student learning in problem-based settings in health professional education. Norman and Schmidt (2000) for example suggested that there was little evidence to suggest that PBL curricula resulted in an improvement in students' general problem-solving skills, although they cautioned that problem-solving skills independent of content acquisition may not exist. However, their evidence suggested that PBL does improve both self-directed learning skills and student motivation. They also found that retention of knowledge may be improved by using PBL.

Barrows (2000) noted that PBL was advocated in the writings of Bruner, Gagne and Dewey before its introduction at McMaster University in the late 1960s. Since then numerous research studies have been conducted to evaluate the effectiveness of PBL either as a stand-alone mode of instruction or as parallel problem-based curricula, mainly in health professional education settings. Informed in part by the findings of these studies, many models of PBL emerged and were adopted by medical schools around the world.

Concurrently PBL was tried and tested in engineering education and there is now a growing literature on the use of PBL in engineering degree courses (Clough, 2005; Hadgraft, 1993b; Kolmos et al., 2004; Lloyd, 1989, 1991; Lloyd et al., 2001; Lundgreen, 1990; Perrenet, Bouhuijs, & Smits, 2000). However, while there are some studies in educational settings other than engineering of the learning interactions in PBL classrooms (Evensen & Hmelo, 2000), such studies are almost non-existent in an engineering setting. The few studies that have been reported tend to emphasise quantitative approaches using surveys and such studies are of limited use if we wish to understand what goes on in PBL groups and build theories to inform the practice of PBL. There is therefore a need for more descriptive, naturalistic approaches to theorise on the development of autonomous learners in PBL as well as on the learning cultures that develop in PBL teams (Nisbet, Entwistle, McQuillin, & Robinson, 2005; Perrenet et al., 2000).

This study attempts to address this need by investigating the different learning cultures that emerge in PBL teams and some of the learning outcomes that result. This study was conducted at Victoria University at a time when PBL had just been introduced in engineering courses.

1.2 This dissertation

The study reported in this dissertation aims to investigate the different learning cultures in a first year problem-based learning engineering degree course. It also investigates the ways in which students approach and direct their learning as individuals and as a team and some of their learning outcomes such as disciplinary knowledge, cross-disciplinary knowledge and the innovative thinking skills required for engineering practice. The “life” experienced by engineering students in PBL during their first year undergraduate degree was interpreted through a naturalistic qualitative approach supplemented with interviews and their work-samples.

Chapter 2 presents a detailed review of relevant literature to provide the theoretical framework for this study. The literature involving current trends in higher education particularly in engineering, student learning and problem-based learning, are thoroughly examined. Chapter 3 provides specific details about the research aims and research questions. This chapter also includes details of the ethnographic data collection methods used in this study along with details of the methods used for data analysis and validation.

Chapter 4 presents a description of the PBL program at Victoria University and an introduction to the background of the students who participated in this study. In Chapters 5, 6 and 7 the results of the study are presented. Chapter 5 presents narrative cases of twelve individual students, eight of whom were randomly selected to be the focus of this study. The learning approaches of these students in PBL are illustrated in this chapter.

Chapter 6 is based on narrative cases of the eight teams in which these twelve students were members. The learning cultures adopted by these eight PBL teams are described and analysed in this chapter. In Chapter 7, the learning outcomes with respect to disciplinary and cross-disciplinary knowledge and innovative thinking of these students and their teams are discussed.

In Chapter 8, the findings of this study are triangulated and compared with findings that emerged from the observation of a simulated engineering situation named "the group problem-solving activity". The final chapter, Chapter 9, includes a discussion of the results, the credibility of the findings and the implications for practice and further research.

Chapter 2

Literature review

2.1 Introduction

The role of engineering students in the problem-based learning (PBL) process and its effects on their learning will be the main theme for this study. The shift to PBL represents a shift from teacher-centred to learner-centred education. This study therefore focuses on student responses to this shift in emphasis. Since the purpose of this study was to explore and report on the learning cultures and participation of students in an Engineering PBL program and their learning outcomes in the first year of an electrical engineering degree course, it seemed important to explore the genesis of this concern and to place it into a broader educational context. Accordingly this chapter consists of six main sections:

- The challenges faced by engineering education;
- The pedagogical shift occurring in higher education;
- PBL in higher education and engineering education in particular;
- Implementing PBL;
- Disciplinarity and PBL;
- Creativity and innovative thinking and PBL.

2.2 Challenges faced by engineering education

In the last hundred years our world has changed steadily and more rapidly than it has in the preceding past (National Academy of Engineering., 2005). It has become a healthier, mostly safer and an extremely productive place, where engineering through technology has forged an irreversible imprint on our lives, identity and the society. Clough (2005) argued that it is always dangerous to predict the future of anything. He reported that in 1977, Ken Olsen, founder of Digital Equipment Corporation felt that there was no reason for anyone to have a computer at home. He also reported that in 1981 Bill Gates apparently said 640 Kb of storage space should be enough for anyone.

While Clough (2005) acknowledged that these men were the experts and innovators in their field, he argued that they got it wrong.

Engineering is a field of knowledge and endeavour in which likely technological changes and challenges impact the world and influence the engineering profession (Schön, 1983). Modern engineers revolutionise the world by engaging in all phases of simple to often incredibly complex lifecycle of products, processes and systems that have one feature in common: They meet the changing needs of society (Crawley, Malmqvist, Östlund, & Brodeur, 2007).

Consequently, the engineering industry expects engineers to find not only engineering solutions to a problem, but also economic solutions that have a high potential of being successful. The new skills and perspectives required of engineers are expected to extend their broader leadership role as the expectations of the technological world on engineers are higher than in the past (Clough, 2005). Yet, engineers commonly do not reflect critically on social issues; nor are they asked to consider these issues at university. Indeed, universities often design and implement engineering courses that are quite successful in training students with diverse views to adopt a stereotypical technology-oriented view (Hadgraft, 1993).

However, today's engineering industry measures an engineer's knowledge and skills not only from the breadth and depth of disciplinary knowledge, but also from the individual's experience in developing personal and professional skills and the ability to work with other engineers and with colleagues from other disciplines (Crawley et al., 2007). Simultaneously, engineers are also expected to address contemporary challenges such as innovation and sustainability or sustainable development, which emerge in high importance for both engineering and engineering education (Mann, Walther, & Radcliffe, 2005). The requirements of the engineering industry are reflected in the competency standards set by Engineers Australia (Retrieved 13th May, 2005, p. 5) Stage 1 competency requirements. The units and elements of competency are presented in the following table 2.1.

Table 2.1 Professional engineer stage 1: Units and elements of competency (Engineers Australia, 2005)

Knowledge base	Engineering ability	Professional attributes
Knowledge of science and engineering fundamentals In-depth technical competence in at least one engineering discipline Techniques and resources General knowledge	Ability to undertake problem identification, formulation, and solution Understanding of social, cultural, global, and environmental responsibilities and the need to employ principles of sustainable development Ability to utilise a systems approach to complex problems and to design and operational performance Proficiency in engineering design Ability to conduct an engineering project Understanding of the business environment	Ability to communicate effectively, with the engineering team and with the community at large Ability to manage information and documentation Capacity for creativity and innovation Understanding of professional and ethical responsibilities, and commitment to them Ability to function effectively as an individual and in multidisciplinary and multicultural teams, as a team leader or manager as well as an effective team member Capacity for lifelong learning and professional development Professional attitudes

A nation's social goals will not be met without a robust engineering community in that country. As we look to our future in an increasingly globalised world, innovation remains central to Australia's prosperity. Science and innovation is a strategic priority for both the federal and the state governments. We need skilled and motivated people to take on the challenges of creating and developing new ideas (DEST, 2004). Innovative solutions would make us outstanding competitors among the rest of the world. We need to develop expertise based on innovation, to create cutting-edge technological services that offer higher value and may lead the way at the high-end of the economic spectrum (Clough, 2005).

According to Jackson (2006), the ability to imagine and invent new worlds for ourselves is one of our greatest human assets and the origin of all human achievement. Creativity has become critical to surviving and thriving because it enables a person to identify appropriate problems unnoticed by others and solve them. As roles and relationships in families and community structures are changing rapidly, newer generations have a much more active role in the society than in the past. Alongside all these challenges, information and communication technology provides opportunity for creative minds in the ways we represent and engage with the physical and social world (Craft, 2006).

Professionals tend to work in environments that continually attract change and innovation (Dunlap, 2005). This is particularly true for engineering as technology is continually invaded by change. In a fast changing world, the ability to generate ideas to create products and solutions to problems that satisfy social and consumer demands needs a creative dynamic between knowledge-creation, entrepreneurialism and consumers. Without new knowledge there will be no products or services to offer, and possibly no effective platforms through which to deliver them. Without entrepreneurialism it is not possible to take advantage of the potential or benefit within new knowledge and take that to market. Without take-up by the market, be that social or economic in conception, innovation will merely be novelty (Smith-Bingham, 2006).

Craft (2006) argued that globalisation of economic activity has brought with it an increased competitiveness for markets driving the need to raise the levels of educational achievement of their potential labour forces. Accordingly what is required in terms of academic achievement is changing. It is no longer enough to have depth and grasp of knowledge. This implies that a graduating engineer is therefore required to develop the skills not only to create brilliant new ideas, but also to transform those ideas into new realities thus adding value to the society. It also indicates that many of the problems faced by engineers these days include both “hard” (technological) aspects and “soft” (social) aspects.

If we want engineering graduates to succeed in this changing environment, are we preparing them for it in the classroom? Can the learning that takes place in the protected environment of a tertiary institution be transferred into other, rough-and-tumble learning contexts? How do we help students continue to learn when no longer under the supervision of their lecturers or tutors (Candy, Crebert, & O'Leary, 1994)? To address these issues the engineering curriculum requires major rethinking (Hadgraft, 1993b). That is, it requires restructuring of engineering programs, reallocation of teaching and learning resources, and refocusing of faculty and professional society time and energy to strengthen the educational infrastructure and to educate engineers to tackle the challenges of the future.

Engineering education stands to be marginalized if the education system is passive. The education that we provide to engineers must prepare them to be more than merely fulfilling a technological function (Murray, 2005). It needs to prepare engineers to become leaders in making wise decisions about technology and policies that will foster innovation (Ben-Ari, 1998).

Essentially, engineering education must aim to produce technically excellent graduates who are capable of pushing new frontiers by collaborating with colleagues from other disciplines and creating innovative solutions in a constantly changing global economy (National Academy of Engineering, 2005). These aims note the importance of improving the recruitment and retention of students, and making the learning experience more meaningful to them (Kerns, Miller, & Kerns, 2006). The aims challenge how engineering educators can more effectively share with students their current and potential passion for designing systems, structures, and devices to solve problems and their confidence that engineering is a profession that offers rich rewards for serving the interests of society (Crawley et al., 2007).

At the same time, the student body in engineering as in other higher education fields is becoming more diverse. Recent experience indicates that cohorts of students entering engineering courses include an increasing number of students who have varied interests and engage in paid part-time or fulltime work (Krause, 2005). Engineering schools in universities, particularly in Australia, are characterised by students with a high level of diversity including age, ability, educational background, socio-economic status, language background and ethnicity. This high level of diversity presents a substantial challenge to universities especially as they focus on strategies to improve student engagement in activities associated with high quality learning. This challenge is particularly true for students who are the first in their families to attend university, a place that is both foreign and culturally alienating (Krause, 2005). Hence courses should adjust accordingly – they must be inclusive.

To summarise, this section has explored some of the challenges faced by engineering education. Particularly this section has identified how the field of engineering is rapidly changing to accommodate the changing needs of the society. It necessitates pedagogical rethinking in engineering education to teach future engineers technical knowledge along with generic skills. It also necessitates a shift in focus from teaching engineering to student learning in engineering.

Advocates of problem-based learning in professional higher education settings claim that PBL is particularly beneficial to enhance student learning as they become independent inquirers. It is also claimed that learning to problem-solve real life problems in a group setting such as PBL enhances the development of problem-solving skills, team-work skills, disciplinary and cross-disciplinary knowledge and innovative thinking skills. In order to explore the changing paradigm in engineering education, it is important to take a broader perspective and look into the changing pedagogy in professional higher education settings. Therefore, the next section deals with the changing pedagogy in professional higher education courses.

2.3 Changing pedagogy in professional higher education courses

A major development in our understanding of student learning in higher education originated in Sweden with Marton and Säljö's study of surface and deep approaches to learning (Biggs, 2003). Ramsden (2003) and Biggs (2003) used the research findings that flowed from this study to argue persuasively that teaching is most effective when it focuses on creating a learning environment that encourages students to adopt a deep approach to learning. This shift in focus from a focus on teaching to a focus on student learning has been characterised as a paradigm shift in higher education (Barr & Tagg, 1995).

A deep learning approach helps students to construct meaning and develop understanding of what they are studying. A focus on the transmission of information, on the other hand, is likely to result in students using a surface approach to learning associated with memorising rather then understanding. Biggs (2003) observed that students whose intention is to achieve only a minimal pass tended to use a surface learning approach. To encourage use of a deep approach, Biggs (2003) advocated an approach to teaching based on principles that he entitled "constructive alignment", an amalgam of constructivism and alignment (Biggs, 1996a). Teaching based on these principles, he argued, both aligns learning objectives, teaching method and assessment and emphasises a constructivist approach to learning.

Constructivism has a long history in cognitive psychology and takes several forms such as individual, social, cognitive and post-modern constructivism (Steffe & Gale, 1995). In the constructivist paradigm learning is seen as an active process of constructing and reconstructing knowledge (Ben-Ari, 1998). According to Ben-Ari (1998) knowledge is acquired recursively and learning must be assisted by guidance from the teacher and feedback from both teachers and other students. The best learning outcomes are thus the result of cognitive and social interactions (Biggs & Moore, 1993).

Central to constructivism is the notion that learners play an active role in 'constructing' their own meaning (Le Cornu & Peters, 2007). However, constructivist pedagogies represent a synthesis of cognitive and social perspectives, where knowledge is seen as both personally constructed and socially mediated. Classrooms are seen as places where "inquiry and co-construction as well as other forms of student-centred, discourse-based interactions dominate" (Holt-Reynolds, 2000, p. 21). Holt-Reynolds (2000) argued that the act of teaching is being reframed as building on learners' prior knowledge and engaging them in purposeful, contextualised, challenging and interesting learning activities.

Constructivism always implies that knowledge can neither be transmitted nor can it be neutral. Knowledge is always constructed, negotiated, propelled by a project and perpetuated for as long as it enables its creators to organise their reality in a viable fashion (Larochelle & Bednarz, 1998). It has prompted the development of challenging, conceptual and methodological educational situations which stress the need to encourage greater participation by students in their appropriation of scholarly knowledge (Larochelle & Bednarz, 1998). It is argued that constructivist learning outcomes are most likely to result from teaching approaches based on self-directed and peer-assisted learning (Stroot et al., 1998), experiential and real-world learning (Kolb, 2007), resource-based and problem-based learning, reflective practices (Schön, 1983) and critical self-awareness (Ramsden, 2003).

If learners are to construct their own knowledge, they need to develop as autonomous or self-directed learners. Candy (1994) describes self-directed learning as a kind of learning which takes place when the learner takes responsibility for specifying individual learning needs, goals and outcomes, planning and organising the learning task, evaluating its worth and constructing meaning from it. It provides the opportunity for students to take control from teachers whose role becomes one of a resource and a facilitator of learning who guides the learning process according to the needs of the learner at any one time in a collaborative process (Candy et al., 1994).

Candy et al. (1994) claim that some of the advantages of constructivist pedagogy include experiential learning and reflective practice. Experiential learning blurs the differences between learning at a university and learning in the workplace and emphasises learning that is more comparable with that encountered in the world of work. Reflective practice is grounded in the personal experience of the learner (Boud, Cohen, & Walker, 1993). Central to the concept of reflective practice is the fact that there is a form of knowledge (an epistemology of practice) that differs from the theoretical abstractions which most people are taught in university (Candy et al., 1994, p. 146). Reflective practice is about learning effectively from one's experience and is an important skill for life long learning. This leads to the development of critical self-awareness through reflection on any particular learning experience (Schön, 1983).

According to Savin-Baden (2000), there are few frameworks that help us to understand the relationship between the learning context and the experience of the learner. She advocated a critical pedagogy, based on the ideas of Freire (1993) that is not simply another perspective on adult learning but rather a shift in belief. Critical pedagogues argue that all forms of education are contextual and political whether or not teachers and students are consciously aware of the process (Weimer, 2002). Learning must therefore occur in a social and cultural context and this necessarily influences what and how people learn. Freire (1993) saw education as a vehicle for social change. As an educator in Brazil, he developed theories of education and social change as he taught illiterate peasants to read and empowered them to challenge corrupt political regimes.

Another key aspect of the changing paradigm in higher education is the priority placed on preparing students to be lifelong learners. Recognising the significance of lifelong learning, in 1972 UNESCO set up an International Commission on the development of education, under the chairmanship of Edgar Faure, a former French

Prime Minister and Minister of Education. The following year, the International Commission published its report under the title: *Learning to be: The world of education today and tomorrow*. It was in many ways a visionary document, aimed at providing a framework for all levels and types of education in all parts of the world. An important and influential statement about the contribution of lifelong learning to human development, its first and foremost basic recommendation was that life long learning should become the master concept for educational policies in the years to come for both developing and developed countries (UNESCO 1972).

Candy (1994) suggested a model of the undergraduate curriculum that emphasised the development of the skills of lifelong learning. He proposed that learning-to-learn skills include and subsume many other generic skills. If they were to be considered central rather than the edge of curriculum, they would provide a unifying principle for much of the content taught in any given undergraduate program, as well as providing foundational skills that would enhance learning throughout the rest of the course.

Another way of characterising the paradigm shift in higher education is to see it as a shift from a teacher-centred pedagogy to a student-centred pedagogy. Weimer (2002), however, warned about confusing learner-centred and student-centred approaches to teaching. She stated that a student-centred approach implies a focus on student needs. It is an orientation that gives rise to the idea of education as a product, with students as customers and the role of the teaching staff as serving and satisfying the customer. When the product is education, the customer cannot always be right, there is no money-back guarantee and tuition fees do not buy the desired grades. On the other hand, being learner-centred focuses attention on what and how the student is learning, the conditions under which the student is learning and whether the student is retaining and applying the learning. Thus the student becomes an important part of the equation and the direct recipients of efforts aimed at promoting learning constructively.

Weimer (2002) suggested five key changes to instructional practice in learner-centred teaching. They are the balance of power, the function of content, the role of the teacher, the responsibility for learning, the evaluation of purpose and processes. She questioned the traditional power structures and the role of authority in the classroom, its effects on student motivation and engagement, and proposed democratic views of education that open up possibilities for different kinds of learning. She argued that, in order to facilitate learning that changes how students think and understand, teachers must begin by discovering students' existing conceptions and then design instruction that changes those conceptions. In learner-centred approaches, content is used rather than covered.

This changing role of content is an important part of the paradigm shift in higher education. Though the teacher may 'cover' a great deal of content in a traditional lecturing approach, students may retain or use little of what they learn (Schmidt & Volder, 1984). Teachers therefore need to create conditions that use active learning in the retrieval and appropriate use of the knowledge needed for future professional practice. Van Der Vleuten and Schuwirth (2004) argued that educational approaches are required that engage students and allow them to play bigger and more active roles in acquiring competence.

This section has explored some of the key features of the ongoing paradigm shift in higher education. It is characterised by a change in focus from teaching to learning, from instructivism to constructivism, from teacher-directed learning to self-directed learning, from passive learning to experiential learning, from school learning to lifelong learning, from teacher-centred approaches to learner-centred approaches and from covering content to using content. The next section introduces PBL as an approach that is consistent with this new paradigm of higher education.

2.4 PBL in higher education

Over the past 25 years higher education institutions that academically prepare students for professional areas such as medicine and law have shifted the focus of their courses to emphasise the development of the capabilities needed for professional practice as well as the development of foundational knowledge. The establishment of professional schools in tertiary institutions has resulted in the reassessment of the balance between the vocational and the academic, and in few cases there has be radical redesign of courses (Boud, 1985). Educators in higher education institutions, particularly those responsible for the education of health professionals, drew from theories of teaching and learning and developed an integrated problem-based curriculum (Savin-Baden & Major, 2004). It is argued that the PBL environment offers a context for the development of autonomous learners because of its emphasis on collective and individual learning motivations and decision-making behaviours (Evensen, Salisbury-Glennon, & Glenn, 2001).

2.4.1 What is PBL?

The idea of PBL is older than formal education itself. It is that the starting point for learning should be a problem, a puzzle or a query that the learner wishes to solve. One of the reasons that PBL is still presented as an innovation in modern institutions is that the older conceptions of knowledge and learning on which it is based have been subordinated to the academic subject disciplines in which most teachers have been educated. However, learners are faced with a sharp contrast between their subject-centred education and their problem-solving experience (Boud, 1985).

Problem-based learning is a learner-centred approach to teaching and learning which is mostly constructed around a series of problems selected by the teacher (Barrows & Tamblyn, 1980). In a PBL setting students learn in collaborative groups by solving problems in a sequential process under the facilitation of a teacher (Barrows, 1986). Barrows and Tamblyn (1980) provided a six-stage PBL process based on their experience in health professional education at McMaster University. The stages are:

- The problem is encountered first in the learning sequence before any preparation or study has occurred;
- The problem situation is presented to the student in the same way it would present in reality;
- The student works with the problem in a manner that permits his ability to reason and apply knowledge to be challenged and evaluated, appropriate to his level of learning;
- Needed areas of learning are identified in the process of work with the problem and used as a guide to individualised study;
- The skills and knowledge acquired by this study are applied back to the problem, to evaluate the effectiveness of learning and to reinforce learning;

- The learning that has occurred in work with the problem and in individualised study is summarised and integrated into the student's existing knowledge and skills.

Hmelo-Silver (2004) argued that the first step in the PBL process is getting students to "encounter" the problem. She claimed that students develop a better understanding of the problem when they plan and analyse the problem by identifying the significant facts from the scenario. They then represent the problem and generate hypotheses about possible solutions. More importantly, as they generate hypotheses they also start to identify their knowledge deficiencies relative to the problem. These knowledge deficiencies become learning issues that students research during the self-directed learning phase. Following this, students apply their newly learned knowledge in problem-solving and thus evaluate their hypotheses in light of what they have learned. During this knowledge application process they reflect on the abstract knowledge gained. The teacher helps guide the learning process through open-ended questioning designed to get students to make their thinking visible and to keep all the students involved in the group process (Hmelo-Silver, 2004).

The PBL process described by Hmelo-Silver (2004) is similar to the process described by Barrows and Tamblyn (1980) except that she investigated the PBL process in an educational psychology course by focusing on collaboration and motivation. Through her findings she stressed that "it will be naïve to believe that the medical school model of PBL could be directly imported into other settings without considering how to adapt it to the local context, goals and the developmental level of learners" (p. 260).

According to Perrenet, Bouhuijs and Smits (2000) PBL is a learning approach that is most commonly constructed around a series of problems/projects selected by a teacher. Learning in the PBL process can be classified into three phases. The first phase is encountering a problem or problems. Students identify their learning needs and also establish a co-operative setting, generally with the assistance of a tutor or facilitator in this phase. The second phase is the autonomous or self-directed study phase and the last phase is applying newly gained knowledge to the problem, again in a co-operative setting with the help of a facilitator (Perrenet, Bouhuijs, & Smits, 2000). This approach integrated the six-staged McMaster model suggested by Barrows and Tamblyn (1980) into its three phases.

A pilot systematic review and meta-analysis of PBL studies (Newman, 2005), reported that the availability of limited high quality designs from existing reviews is not sufficient to provide solid evidence about the effectiveness of different kinds of PBL used in different contexts with different group of students. In his pilot review, Newman highlighted that a number of conceptual, methodological and practical problems needed addressing by those interested in PBL.

2.4.2 Models of PBL

PBL approaches situate learning in meaningful, experiential learning activities, in which students learn by solving problems and reflecting on their experiences (Barrows & Tamblyn, 1980; Hmelo-Silver, 2004). PBL takes different forms depending on the context and the discipline in which it is implemented as a teaching and learning strategy. Savin-Baden and Major (2004) suggested that there are eight modes of curriculum practice in PBL in academic institutions around the world. They are:

- The single module approach – one PBL module in the entire program likely in the final year;
- The problem-based learning on shoestring approach – PBL is used by a few teachers and implemented with minimal cost and interruption due to resistance from other teaching staff members;
- The funnel approach – curriculum is designed such that PBL is funnelled in the course after commencing with lecture-based learning;
- The foundation approach – used mainly in engineering curricula due to the assumption that students need to be taught foundational knowledge before they begin solving problems;
- The two strand approach – PBL is a vital component in the curriculum but used simultaneously with other learning methods;
- The patchwork problem-based learning – entire curriculum is designed using PBL strategy. However, different modules of the course run concurrently, not consecutively;

- The integrated approach – entire curriculum is designed using PBL philosophy. Students solve one problem at a time and the problems are integrated sequentially;
- The complexity model – transcends subjects, disciplines and university curriculum impositions, and embraces knowledge (discipline specific), self (educational identity in relation to the subject area), actions (competencies acquired through doing) and curriculum organisation principles.

They suggested that the major difference between PBL and other similar approaches to learning is in the understanding of what counts as curriculum for its developers.

Dunlap (2005) pointed out that in problem-centred learning environments students have opportunities to practice applying their content knowledge and workplace skills while working on authentic, contextualised problems and projects. The terms problem-based learning, problem-centred learning, problem-centred instruction are often used interchangeably to refer to instructional approaches that use real world simulated, contextualised problems of practice to motivate, focus and initiate content learning and skill development (Boud & Feletti 1991).

However, Savin-Baden and Major (2004) clearly differentiate between problem-solving learning and problem-based learning. They argued that PBL is one of many active learning approaches, in which students are active participants and independent critical enquirers who own their own learning experiences. On the other hand, in problem-solving learning the role of a student is a problem solver who acquires knowledge through bounded problem-solving.

Hmelo-Silver (2004) suggested that beyond the "problem first" emphasis, problem-centred learning approaches such as cognitive apprenticeship, case studies, anchored instruction and intentional learning environments tend to share common instructional characteristics. The approach to learning is context sensitive and situated, and the process students follow replicates the commonly used systematic approach to resolving problems or meeting challenges encountered in workplace and the world at large. As the problems that students work on reflect the true nature of the world, they are therefore loosely structured. Students are actively involved in the learning process from problem introduction to solution implementation and reflection on the learning process, which is very different to finding formulaic solutions in lecture-centred learning environments. Students set their own learning goals and create action plans to drive learning activities, conduct information gathering and research, reflect on what they have learned and how they have learned, work collaboratively with colleagues to pool their knowledge and skills, share the results of their inquiry and engage in peer tutoring and ultimately solve the problem (Dunlap, 2005).

In Denmark, another variant of PBL has developed, namely problem-oriented and project-based learning or POPBL. This variant also starts with the consideration of a problem in a given context. However, the kinds of problem used are rather different in scale, typically extending over a complete semester or year, and instead of providing the impetus for initial learning in professional subjects project-orientation problems shape the entire educational experience and set it in a technical, social and political context (Kolmos et al., 2004).

Project-orientation has been a conventional part of British Science and Technology Education at university level for more than three decades. It is accepted as a valid and important aspect of the training of scientists and engineers. Curriculum reform in higher education in the mid seventies of the last century suggests that during the process of acquiring knowledge and skills in a course of study at university level, encountering project-orientation for the first time presents great difficulties. It is hard to accept that the familiar curricula accessories with which most of us are comfortable – syllabuses, lectures and formal examinations – has not been rearranged or redesigned, but almost completely discarded. The core idea behind project-orientation in the 1970s was that the project work alone should determine the content of the course, contrary to the dictates of a conventional curriculum (Cornwall, Schmithals, & Jaques, 1976).

Kolmos (1996) argued that "the claim of a non-directive attitude, the project method of teaching is basically teacher-centred" was both right and wrong (p. 142). In spite of the challenges project-work poses to the learning process, she maintained that both project work and problem-based learning emphasise the learning process instead of the teaching process. The characteristics of the Danish model of project-work which integrates problem-based learning and project-work include "problem-orientation and inter-disciplinarity, open curriculum and experience based learning, basic year and gradual specialisation, project work in study groups" (Graaff & Kolmos, 2007).

In engineering education at Aalborg University, problem-orientation is integrated into project-work in at least three different ways. The phases of each project include preparation, problem analysis, demarcation, problem-solving, conclusion and reporting. Problems have to be analysed and solved in different ways for all types of project. However, what determines the choice of the problem and the methods used in the project is very different.

Project types are defined in the preparation phase. At this phase, it is revealed whether the learning process is self-directed or teacher controlled (Kolmos, 1996). The three different project types include: assignment project, subject project and the problem project. In the assignment project, the problem, the subject and the methods to be used are chosen beforehand and a considerable amount of planning and control lies in the hands of teachers/supervisors (Kjersdam & Enemark, 2005; Kolmos, 1996). The subject project is characterised by the subjects chosen beforehand. In this type the students either have a free choice of problems within the subject or the problem is given to the students. The students then have a free choice from the number of described methods to solve the problem. The problem project is different from the other two types. This is based on problems as the starting point. The problem determines the choice of disciplines and methods which correspond to the original idea of a problem-oriented learning process. Projects in this type are interdisciplinary and the educational objectives include the ability to analyse and to develop technical skills (Kolmos, 1996; Kolmos et al., 2004).

While Graaff and Kolmos (2007) claimed that the differences seem more complicated and incomprehensible, the ideas of problem-based learning and project-work support and complement each other. They argued that the learning process in POPBL is more authentic than most artificial cases used in PBL as the learning context in which the assignment is presented to student influences their learning process.

Although different models of PBL have emerged since its inception, researchers suggested that there is a strong connection between problem-based learning and other forms of active learning approaches. Schuwirth and Van Der Vleuten (2004) suggested that it is the PBL concept that is important and particular methods are only ways of using the concept. Savin-Baden and Major (2004) argued that if teachers expect their students to be self-directed learners, take control of their learning and understand the context in which they best learn, they need to help their students understand the differences in approaches and the relative amount of freedom that one approach offers over another.

2.4.3 Advantages of PBL

It is argued in the literature that PBL is designed to help students develop competencies that will serve them throughout their professional lives. These lifelong competencies include the ability to adapt and participate in change, deal with problems and make reasoned decisions in unfamiliar situations, reason critically and creatively, adopt a more universal or holistic approach, practice empathy, and appreciate others' perspectives, collaborate productively in groups or teams, identify personal strengths and weaknesses, undertake appropriate remediation such as self-directed learning and meta-cognitive reflection (Engel, 1991).

Activation of prior knowledge, together with the similarity of context in which information is learned and later applied and the opportunity to elaborate on information that is learned during the problem-solving process are claimed advantages of PBL (Bridges, 1992). These conditions have been shown to reduce forgetting and to facilitate retrieval. Elaboration occurs in discussion with peers, peer teaching, exchanging views and preparing reports of what students have learnt during the problem-solving process. Essentially, PBL is designed to encourage deep approaches to learning.

However, the learning outcome achieved by PBL is still a contested issue. Strobel and Barneveld (2008) argued that the reason is because of the differences in defining conceptualisations of learning, effectiveness of learning, and how effectiveness was measured. They compared and contrasted assumptions and findings of meta-analytical research on PBL using a qualitative meta-synthesis approach and argued that PBL was superior when compared to traditional approaches. They concluded that PBL works in particular contexts, especially for workplace learning with a focus on skills and long-term retention and therefore suggested that the researchers should shift from researching effectiveness of PBL versus traditional learning to refocus on studying the differences in effectiveness of support structures to find optimal scaffolding, coaching, and modelling strategies for successful facilitation of PBL.

2.4.4 PBL in engineering

A paradigm shift from a focus on teaching to a focus on learning is underway in engineering schools in many universities. This shift is reflected in the engineering education literature, in that it is claimed that PBL helps students to build extended technological and social understandings along with the appropriate use of new technologies (Hadgraft, 1993b). PBL is also advanced as a means of developing autonomous learners who are effective learners for the rest of their lives.

Although significant research evidence in health professional education supports the claim that PBL is advantageous for students, there is limited research evidence in engineering education that suggested PBL is beneficial to the engineering discipline (Brodeur, Young, & Blair, 2002; Fink, 2002; Hadgraft, 1993a, 1993b).

An example that favoured the implementation of PBL in engineering courses is the study conducted by Dunlap (2005) with 31 "typical-case" undergraduate computer science students studying a PBL capstone course in software engineering. The PBL capstone course was delivered during their final semester prior to graduation to suggest specific instructional strategies that may be incorporated into learning environments to enhance students' self-efficacy. Self-efficacy was defined as an individual's level of confidence and self-judgement regarding their ability to organise and implement actions needed to perform effectively. A self-efficacy scale was used as pre- and post-test measures along with guided journal entries. Students were observed to increase their levels of self-efficacy during the 16 weeks of the course. This study reported students' experiences and the impact of enculturation into the community of practice. That is, the process by which individuals learn and identify their domain culture and critiqued the statement that the activities of a domain are framed by its culture (Brown, Collins, & Dugid, 1989, p. 34).

Dunlap (2005) concluded that conventional schooling restricts students' exposure only to the culture of the classroom and not to the culture in which the content and skills they are learning are naturally applied. Their exposure to the tools of a domain's culture can be antithetical to the requirements of successful professional activity within that domain. Therefore, students may develop “inert” knowledge and find it difficult to transfer it to professional activity. This study concluded that although the acquisition of knowledge and skills makes it possible for performance to occur, students without self-efficacy did not even attempt performance.

Another study that favoured PBL in an engineering setting was conducted by Du (2006) in which she demonstrated that basic engineering training is made up of a combination of science and engineering skills along with the learning of certain practices, norms, beliefs and values. She highlighted the importance of identity construction in engineers by looking into the everyday life of engineering students in a PBL setting. She concluded that the PBL process in engineering leads to “mutual construction”, a term which she used to describe changes both in individuals as well as in communities.

There are even fewer reports of the evaluation of whole engineering PBL programs. The report on the development of project organised problem-based learning in Danish engineering education by Kolmos, Fink and Krogh (2004) is a notable exception. This study reported that the pedagogical model which centred on problem-based, project organised teamwork, was evaluated to be an absolute strength of the educational system as the model focused on professional knowledge and competencies, substantial co-operation with the industry and thereby employability of its graduates.

2.5 Implementing PBL

Introductory courses in most disciplines seek to familiarise students with the basic concepts, vocabulary and skills particular to that discipline. But equally important is helping students understand how that body of knowledge evolves and how that body of knowledge affects our daily lives and the society of which we are part. Constructivism has provided a new view of how students learn. Certain methods of education, such as problem-based learning and assessment, are often seen as almost identical with constructivism’s underlying theory of teaching and learning (Schuwirth & Van Der Vleuten, 2004).

Woods (1985) categorised learning processes into teacher-centred, text or media-based and problem-based learning. Students have no or limited control over their learning in situations other than in problem-based learning. In teacher-centred learning students are locked into the pacing and sequencing used by the teacher who personifies the image of a professional in the particular discipline. On the other hand in text-based or media-based learning, it is more difficult for students to see a professional in action, and to assimilate the so called tacit information of the discipline (D. Woods, 1985).

According to Van Der Vleuten and Schuwirth (2004) the ideal method of implementing PBL needs careful analysis of the content, the curriculum and its goals. On the other hand, Savin-Baden and Major (2004) argued that cultural and institutional constraints along with issues across disciplines affect the design of PBL curricula. They suggested that designing a curriculum based on content and disciplinary knowledge first and then trying to make it problem-based generally ends in failure. They insisted that "in problem-based curricula the problem scenario should serve as the central component of each module so that lectures, seminars or skill laboratories can feed into them" (Savin-Baden, 2003, pp. 119-120). Thus just as the problems come first for the students, they should also come first for curriculum developers.

2.5.1 Problems

Savin-Baden and Major (2004) noted that when implementing PBL, one of the common concerns to many teachers in PBL are what might count as a problem and the complexity of the problem design. They noted that some teachers design their own problems while others purchase PBL problems or download problems from the Internet. They argued that most teachers in PBL set out to design problems that are based only on the content that they feel their students need to learn by jointly deciding, with other teachers, how much content can be packed into a PBL programme. While they concede that this method may work at a basic level to cover the content knowledge students are expected to acquire, it results in learning that is highly teacher-directed and students learn pre-prescribed chunks of knowledge. They suggested that teachers need to recognise different kinds of knowledge and that their recognition may lead to helping students realise that different problems may require different application of those kinds of knowledge. The balance between discipline knowledge and process skills such as problem-solving skills and team-work skills must be taken into account when designing problems for a course or a programme.

It is commonly argued in the literature that the selection or design of the problem or project plays an important part in achieving the goals of PBL. Hmelo-Silver (2004) argued that in order to foster flexible thinking, problems need to be complex, ill-structured, open-ended and must intrinsically motivate students as they engage in problem-solving. Ill-structured problems to her means complex problems that cannot be solved by a simple algorithm. An open-ended problem also has nearly the same definition except that it instigates creativity as there could be multiple correct answers for the problem (Craft, 2006; Lumsdaine, Lumsdaine, & Shelnutt, 1999; Treffinger & Isaksen, 1994). Savin-Baden and Major (2004) suggested that problems should be designed in such a way that helps students to both individually and collectively decide their learning needs within their PBL team.

Similarly, Hmelo-Silver (2004) suggested that a good problem must be realistic and resonate with students' previous experiences and allow students to evaluate the effectiveness of their knowledge, reasoning and learning strategies. She claimed that good problems foster communication skills as students present their plans to the rest of their class. She argued that such activities when incorporated in the problem, helps students defend themselves to others in the group. Thus they not only articulate their current state of understanding but also enhance their own opportunities for knowledge construction. She also argued that the necessity of gathering knowledge from a wide range of multi-disciplinary sources will allow students to see how knowledge is a useful tool for problem-solving and will help them build extensive and flexible knowledge because information is not learned in isolation. Yet, she claimed that having good problems is a necessary but not a sufficient condition for effective PBL.

Thus, problem design or selection in PBL is complex as many factors need to be considered. This is different for different disciplines as they regard knowledge differently. Furthermore, the complexity of problems is also a necessary factor to be considered depending on the year level at which the PBL unit is administered. In any case, problems should be designed such that it motivates and continues to motivate critical inquiry and thereby effective student learning.

2.5.2 Facilitation

The introduction of PBL requires a radical change in the way students learn in engineering programs and the role that academic teaching staff play in facilitating student learning (Gabb & Keating, 2006). Researchers have constantly emphasised the importance of facilitation in PBL. Facilitation, a subtle skill, includes identifying when an appropriate inquiry is being conducted, what progress is being made and when the PBL process has stalled. In a study of an expert PBL facilitator, Hmelo-Silver (2002) found that the facilitator accomplished the role largely through meta-cognitive questioning and questioning that focussed student's attention and elicited causal explanations. The study found that the facilitator used a variety of strategies to get students to construct causal models and explain their reasoning to an extent where they realised that the limitations of their knowledge necessitated learning issues. This study demonstrated that an expert facilitator has a flexible set of strategies that can be tailored to different stages of the PBL process.

Woods (1996) noted that teachers must provide "coaching to help students to bring out the best in their group" (p. 1). He suggested that the coach should:

- Ask leading questions to help students explore the richness of the situation and guide their critical thinking;
- Help students reflect on their experiences to develop personal and group skills as well as to improve their problem-solving experience;
- Monitor their progress to help them effectively problem solve;
- Challenge their thinking to nurture deep approaches to learning;
- Raise issues to help them consider intended goals;
- Stimulate, encourage, create and maintain a warm and safe atmosphere to help individuals share their experiences and ideas with confidence.

Windschitl (2002) argued that "teachers must learn to capitalize on, rather than suppress, differences in students' existing understandings due to background; they must become critically conscious of the dynamics of their own classroom culture; and they must attend to patterns of classroom discourse as well as to the thinking that goes with them" (p. 153). The role of a facilitator in a team is critical to making PBL function well (Savin-Baden, 2003).

PBL embodies the cognitive apprenticeship model with its emphasis on making thinking visible (Brown et al., 1989; Collins, Brown, & Holum, 1991). This model suggests that the key roles of the facilitator are modelling, scaffolding, coaching and fading. The facilitator is an expert learner who models good strategies for learning and thinking rather than demonstrating expert knowledge in content itself.

The facilitator scaffolds student learning primarily through the use of questioning strategies (D. Woods, 1985). Woods (1985) defines scaffolding as processes by which students learn with help from their facilitator that which they could not achieve alone, which clearly maps to both the scaffolding and coaching roles of the cognitive apprenticeship model. As suggested by Schön (1983) facilitators should open up an inquiry rather than terminating a discussion and progressively fade their scaffolding as students become more experienced with PBL until finally the learner may adopt many of the facilitator's roles. The facilitator is also responsible for monitoring group processes. This monitoring assures that all students are involved and encourages them both to externalise their own thinking and comment on each other's thinking and thereby reflect on their own learning (Hmelo-Silver, 2006).

2.5.3 Assessment

Assessment strategies need to be aligned with both the desired learning outcomes and learning activities of PBL. A study conducted by Savin-Baden (2004) in four different disciplines using PBL explored both staff and student experiences. She found that many forms of assessment undermine collaborative learning and the team process in PBL. Concerned about the future of PBL communities, Savin-Baden (2004) suggested that it is important to recognize disciplinary differences in PBL and adopt assessment approaches that fit both with PBL and the disciplinary context in which it is used.

Savin-Baden (2004) argues that assessment issues in PBL will remain contested ground unless the emphasis is shifted from a performative approach and importance is given to the learning process. She contends that it is vital to de-mystify assessment criteria and help students become stakeholders in the assessment process. She found that students in many programs that use PBL feel that their learning is unrewarded, that they are disempowered by complex assessment mechanisms and that working in teams is undervalued. She advocates the design of assessment systems that are meaningful to students and are aligned to PBL and the subject context.

2.5.4 Student learning approaches

Learning tasks in PBL require students to undergo experiences similar to a workplace setting. Therefore, it is likely that students may get acculturated into work environments and develop skills and capabilities that they can transfer into their own professional practice after graduation. However, as mentioned earlier, students studying engineering courses these days are characterised by diversity. They have varied age groups, school backgrounds, experience backgrounds and have rather different learning experiences. This means that they would have different learning needs and may approach learning differently.

Biggs (2003) highlighted this by comparing two students. Student A was a traditional school leaver who starts undergraduate study with a high level of academic involvement and adopts learning by applying, generating, reflecting and theorizing. Student B, on the other hand, was a non-traditional student with a less than positive school experience, who starts undergraduate study by memorizing and note taking, failing to relate what is being taught to their existing knowledge. Student A tends to use higher cognitive level processes even if the teaching method is passive (through lectures and assignments). However, Biggs argues that student B can achieve at the level of student A only if an active learning approach such as PBL is adopted.

Originally Biggs and Moore (1993) suggested three different learning approaches surface, deep and achieving; each with a corresponding motive and a strategy. Surface approaches arise out of an extrinsic motivation and the student carries out tasks to gain a paper qualification. The surface motive is focussed on the product. Students adopting a surface approach display willingness to engage in learning tasks mainly to pass minimally with minimal trouble or effort. These students adopt a strategy where the focus is on what appears to be the most important topic for examination and aim to produce or reproduce them. Because of this focus, they do not see interconnections or implications of what they learn.

Deep approaches arise out of intrinsic motivation or curiosity to seek the meaning of what the student learns. The deep motive is focussed more on the process of learning rather than the product. The deep motive gives rise to a strategy in which the student relates the subject material to personally meaningful contexts or to existing prior knowledge depending on the subject concerned. Deep processing involves processes of higher cognitive level than "rote learning", with the student instead searching for similarities relating to previous knowledge, theorising about what is learned and deriving extensions and exceptions.

An achieving approach is similar to the surface approach because of the focus, which is the end product. Students who adopt this approach tend to use strategies to maximise the chances of obtaining high marks rather than obtaining a minimal pass. Obtaining high grades and winning prizes drives them to engage with assessment tasks. However, such engagement is the means and not the end. The focus and the nature of engagement depend on what earns the most marks.

According to Biggs, the ultimate aim of professional education is to develop the functioning knowledge of future professionals. This involves the integration of declarative (abstract and conceptual) knowledge ("know about") and procedural (specific and pragmatic) knowledge ("know how") together with the conditional knowledge ("know when and why") required to identify the circumstances for using them in solving problems, designing buildings, planning teaching or performing surgery – teaching should focus on developing the functioning knowledge of engineers.

2.5.5 Learning in teams

Learning in teams is an integral part of PBL and it is also one of the most challenging for many students and many facilitators. Lave and Wenger (2002) viewed learning as becoming members of a community of practice and that such communities are based on the assumptions that learning is fundamentally a social phenomenon and that knowledge is integrated in the life of communities that share values, beliefs, languages and ways of doing things. PBL can thus be conceived as learning in a community of practice.

Research into learning in teams is therefore particularly germane to PBL (Kaufman & Mann, 2001). At an operational level, Jaques (1992) suggested that teaching and learning in small groups is a valuable part of the all-round education of students. It allows them to negotiate meaning, to express themselves in the language of the subject and to establish a more intimate contact with academic staff than more formal methods permit. It also develops instrumental skills such as listening, presenting and persuading. As the team develops maturity and ability, relationships develop and leadership styles evolve (Tuckman, 1965).

Jaques (1992) pointed out that support, commitment, enjoyment and imagination is missing from most academic courses. He suggested that the first three may be created in a group environment where open communication, involving trust, honesty and mutual respect takes place and imagination should blossom in this environment.

While there is a considerable literature around the PBL processes, there are relatively few empirical studies of how to help students to function well as part of a PBL team. There are even fewer studies that have investigated how students behave in PBL groups. An example of this latter type of study is that of Cotton, Smith and Lait (2002) concerning teamwork in an inter-professional undergraduate PBL setting. This study was quite limited in that it was conducted in a course that involved groups of medical and nursing students on clinical attachment for a half-day session. As students entering different health professions have few opportunities to work together, it focused on the ethical issues located around teamwork, the roles of other professionals within health teams, the development of mutual respect for expertise and recognition of the value of supporting colleagues (Cotton et al., 2002).

2.5.5.1 Co-operative and collaborative learning in teams

Johnson and Johnson (2004) argued that extraordinary achievement comes more often from co-operative groups than from isolated individuals competing and working alone. This is particularly true in the case of PBL as PBL not only involves students working cooperatively in groups or teams but also engaging in collaborative learning. It is one thing to cooperate in solving a problem but quite another thing to learn collaboratively in a group. Johnson and Johnson (2007) suggested that co-operative learning ensures that all students are socially integrated into networks of positive peer relationships. They defined this student learning behaviour as positive interdependence.

On the other hand, Hmelo-Silver (2002) argued that collaborative learning includes establishing common ground, resolving discrepancies and negotiating actions that a group will take before coming to an agreement. She noted that collaborative learning is more demanding than co-operative learning and that collaboration requires an open exchange of ideas and engagement by all group members. Explaining one's ideas is important for productive collaboration and also serves to enhance learning as a team. The hypothesis that small group structure in PBL helps distribute cognitive load among the members of the team, taking advantage of group members' distributed expertise adds fuel to and helps students become experts in particular topics. Previous research suggests that group discussions and debates in PBL sessions enhance problem-solving and higher order thinking and promote shared knowledge construction (Hmelo-Silver, 2004).

There are some research studies that compare the effects of collaborative learning with the effects of lecture-based teaching methods. An example is the study conducted with students in Harvard's "New Pathways" curriculum, a hybrid PBL program. This study reported on student experiences of PBL, who evaluated their first two years of medical studies as stressful, engaging and difficult. On the other hand, students in the lecture-based mode labelled their experiences as non-relevant, passive and boring (Moore, Block, Style, & Mitchell, 1994).

Few researchers have described the process or factors that are responsible for the successful collaboration in PBL teams. A notable exception is a study that was conducted to explore the cognitive interactions taking place between students in tutorial groups at the Maastricht Medical School (Visschers-Pleijers, Dolmans, Wolfhagen, & Van Der Vleuten, 2004). This study reported that cognitive interaction such as exploratory questioning, cumulative reasoning, and handling knowledge conflicts occurred in the PBL groups that were observed and that collaboration favoured co-construction, which is the indicator of individual and collaborative knowledge construction in a group.

Barnes (2005) stated that the majority of studies have focussed on the cognitive and meta-cognitive aspects of interactions and that the social aspects are unexplored by many. In a multi-site case study of classes engaging in collaborative learning, she argued that poor communication and social relationships within a group can result in failure to engage fully with the task, or can limit the range of solution pathways considered. In order to avoid such situations she suggested that socio-norms be established to monitor individual accountability and responsibility towards learning in collaborative groups.

The common idea that comes from the literature is that collaboration does not just happen. Learning to collaborate through practice requires a clear and co-ordinated strategy for learning about working together in a group and improving co-operative skills. This includes individual's accountability in a group, sharing responsibilities, assuming various team roles and maintaining a positive and effective relationship with team members.

2.5.5.2 Team roles

Belbin (2007) identified nine different "team roles" that underlie team success and classified those nine roles into three different orientations:

- Team members who assume action oriented roles into:
  - Shapers – people who challenge the team to improve
  - Implementers – people who turn ideas of their team into practical plans
  - Completers – people who see the problem is completed thoroughly;
- Team members who assume people oriented roles into:
  - Co-ordinators – people who take up leadership roles
  - Team-workers – people who provide support and make sure the team is working together
  - Resource investigators – people who explore available options;
- Team members who assume thought oriented roles into:
  - Plants – people who come up with new ideas and approaches
  - Monitors – people who analyse and evaluate other members ideas
  - Specialists – people who have the skills to get the job done.

He suggested that if team members have similar weaknesses, the team as a whole may tend to have that weakness. If team members have similar team work strengths then they may tend to compete rather than co-operate for the team tasks and responsibilities that best suit their natural styles (Belbin, 2007).

It is important to note that Belbin identified these roles as contributing to the success of a team in a work-based setting. His argument therefore works best when individuals are assigned particular roles for optimising team performance. However, learning teams should be directed to maximise the learning of individuals in the team, which is achieved by providing opportunity for every team member to be a leader, a team-worker, a resource investigator and a co-ordinator for at least once during the PBL process (Savin-Baden & Major, 2004).

2.5.5.3 Power relationships

As a form of learner-centred learning, PBL requires a shift in power from teacher to learner. Weimer (2002) states that student motivation, confidence and enthusiasm for learning are all adversely affected when teachers control the processes through and by which they learn. Teacher authority is often taken for granted in that most teachers are not fully aware of the extent to which they direct student learning.

In learner-centred teaching there needs to be more awareness of questions such as: Who decides what (content) students learn? Who controls the pace (timeline) at which content is covered? Who evaluates the quantity and quality of learning? Who makes most of the important decisions about learning for students? Weimer (2002) suggested that, when teaching is learner-centred, power is shared rather than completely transferred. To get to the heart of what it means to be a teacher and what teachers are supposed to do, Weimer argued that teachers should not make decisions without student input.

While the goal of learner-centred teaching is to equip students with learning skills so sophisticated that they can teach themselves, studies conducted around enactment of power in a collaborative setting suggest that some students have power over others in the way they influence the topic of discussion (Barnes, 2005). This power necessarily need not be related to their capability or content knowledge.

Heylen, Buelens and Vander Sloten (2008) argued that student learning in a PBL group is particularly sensitive to relationships between its members. A teacher's relationship with students in a PBL group also influences student performance. They suggested that it is therefore necessary to

> "create conditions that promote the development of positive intra-group socio-emotional quality, to install cooperative relationships between group members, to create a social environment where team members trust each other, where they feel 'they get on with each other', and where they experience a sense of community and social cohesiveness" (p. 2).

2.5.5.4 Attitudes, behaviours and actions of individuals in teams

Learning in learner-centred settings such as PBL is influenced by many factors. While the attitudes, behaviour and learning approaches of students seem to mainly influence what is being learnt in classrooms, there is evidence that the actions of teachers combined with other significant factors such as the location, resources, course, expected outcomes and the assessment system also contribute to what students learn and how they prefer learning it (Hmelo-Silver, 2004). In this section, however, the focus is on the factors that influence individuals who learn in teams.

According to the theory of reasoned action, individuals consider the implications of their behaviour before they decide to engage or not engage in a given behaviour (Ajzen & Fishbein, 1980). The person's intention to perform or to not perform certain behaviour is viewed as an immediate determinant of the action. This theory classified a person's intention as a function of two basic determinants: attitudinal and normative. While attitudinal is personal in nature, normative is the reflection of social influence. In certain situations conflict between attitudes towards the behaviour (personal) and the subjective norm (social pressures) may arise. To answer such conflicts, it is important to consider the relative importance of the attitudinal and normative factors as determinants of intention.

A person who believes that performing a given behaviour will mostly lead to positive outcomes will hold favourable attitude towards performing that behaviour. The beliefs that underlie a person's attitudes are termed behavioural beliefs. Subjective norms are also a function of beliefs. In this case it is the belief of a person that specific individuals or groups think he or she should perform or not perform the behaviour.

These beliefs are called normative beliefs and often this can be underlying peer pressure in groups. Ajzen and Fishbein (1980) argued that predicting individuals' behaviour may not be very difficult on the basis of the assumption that human beings are quite rational in systematically processing the information available to them. However, theories of situated cognition argued that deeper analysis may be required to identify the determinants of student attitudes, behaviours and actions within the learning context.

Similarly, Bandura (1977) provided a cohesive theoretical framework for analysing human behaviour and thought. He approached the explanation of human behaviour in terms of a continuous reciprocal interaction between cognitive, behavioural and environmental determinants and emphasised the prominent roles played by vicarious, symbolic and self-regulatory processes in socially mediated experience.

The sections above have explored the literature on learning in teams in any educational setting. But, if we wish to understand the student experience of learning in PBL teams, we need to understand how individual students react to a group environment in PBL. We also need to understand the learning culture that develops in such teams and how this affects the student experience. This is the subject of the following sections.

2.5.6 Learning culture

The term "learning culture" or "culture of the learning group" is used predominantly in the literature concerning organisational learning (K. Kennedy & Moore, 2003). According to organisational learning theory, an effective learning culture continuously challenges its own ways of doing things and thereby is subject to continuous improvement (Senge, 2007). The term is also used in further education, where it is suggested that learning cultures have many different manifestations and exists at many different levels as students do not just acquire knowledge, skills and qualification but learn practices (James, Biesta, & Colley, 2007). According to Neal (2005), learning culture in a higher education setting includes such things as the institutional setting, the influences of different groups of people within the organisation, curriculum management and delivery, the values and traditions, and the institution's place in the community.

Kennedy (2002) has noted that culture is not just a matter of overt behaviour and claimed that it also includes the social rules, beliefs, attitudes and values that govern how people act and how they define themselves. While researching the nationwide culture of students in Hong Kong, he studied the influence of Chinese culture in Chinese learning styles by means of survey research, action learning projects and case studies. He found that Hong Kong adult learners were receptive to new modes of learning styles and adopted them quickly.

While there are a number of studies like Kennedy's that explore cultural differences in learning (what might be called "macro-culture" studies), there are fewer studies investigating the behaviours and actions that influence the learning cultures adopted by small groups of students ("micro-culture" studies). Vale (2001) studied the culture of selected computer-based mathematics classes by observing the relationships between gender and behaviour, engagement and attitudes of the students. She identified factors that explained the gendered patterns of behaviour and perceptions by analysing participant engagement, views, behaviours and recurring events in the classroom. She argued that gender plays a role in shaping the socio-cultural nature of the classroom. According to her, the defining elements of the culture of the observed mathematics classroom were

> "the dominance of boys, teacher-directed learning, learning relationships between students where independence, cooperation and competition coexisted and were experienced differently by boys and girls in the class, inequitable participation and achievement including the exclusion of some students and the computer as a source of pleasure, especially for boys" (p. 255).

Le Cornu and Peters (2007) approached learning culture as a holistic collection of practices emerging out of the attitudes, behaviours and approaches to learning of the students and teachers in a constructivist learning environment. Their study identified themes in relation to implementing characteristics of constructivist learning cultures in schools. The themes that they identified included establishing norms for learning, renegotiating the students' roles and responsibilities, explicit teaching of social skills and processes, explicit teaching of meta-cognitive language, skills and processes, renegotiating teacher's roles and processes, and being a reflective teacher.

These and other studies suggest that the culture that develops in a learning group is influenced by the learning approaches adopted by students. Learning approaches, in turn, are influenced by the learning environment determined by factors such as teacher and course characteristics, which themselves also directly influence the learning culture that develops (Mayya, Ramanarayanan, & Rao, 2004).

In the literature on PBL, culture is usually approached with particular reference to cultural learning styles and the learning preferences of students of various ethnic origins (Savin-Baden & Major, 2004). In the engineering PBL literature, the notion of culture is usually associated with creating gender-friendly learning environments as well as training teachers to help students accommodate intercultural competencies (Du & Hansen, 2006). Such studies advocate redesigning the curricula in different ways to accommodate a variety of multicultural learning styles and/or to eliminate the domination of one national culture over the other with respect to students preferred learning styles (Hansen & Du, 2006).

The focus in the studies reported above is on the effects of gender or ethnic background on learning in groups. In the study reported in this thesis, the focus is broader and different to the approaches taken by Kennedy (2002) or Hansen and Du (2006) in that it explores the different learning cultures that develop in PBL teams. Each small group develops its own learning culture that emerges out of the interactions of norms, attitudes, behaviours and student approaches to learning as they work together.

2.5.7 Learning in PBL teams

As noted in several sections above, there is relatively little research into the student experience of learning in PBL teams. That which is reported focuses almost exclusively on how students act in PBL tutorial groups and in many of these studies, the prime focus is not on the student experience but on how tutors manage the group process. There are almost no published reports of research into how students act outside of formal group meetings, in the self-directed study phase of the PBL process. Moreover, most studies of the student experience of PBL are either based on large-scale student surveys for example, Van Berkel & Schmidt (2000) or small-scale observation studies (Schmidt & Moust, 2000), each of which has its limitations. This section explores this literature on the student experience of PBL, particularly the experience of working in PBL groups.

Large-scale studies based on student surveys and measures of student achievement, such as those of Schmidt and his colleagues at Maastricht University, have produced causal models of PBL that include factors relating to the student experience such as tutorial group functioning, group attendance and time spent on individual study (Van Berkel & Schmidt, 2000). Studies such as these shed some light on the student experience, but in an indirect way. As Bereiter & Scardamalia (2000) observe, research of this type is unlikely to illuminate what actually goes on in the 'emergent complexity' of a PBL setting.

Other studies have used observation of what goes on in PBL tutorials for example, Koschmann, Glenn, & Conlee (2000); Barrett (2005); Visschers-Pleijers, Dolmans, Wolfhagen, & Van Der Vleuten (2004). These studies typically focus on discrete segments of a tutorial rather than on the entire tutorial and on a particular facet of interaction between group members rather than the student experience, so seldom illuminate the broad student experience of PBL tutorials. While such studies are often presented as research into PBL group processes, the focus is often on the facilitator rather than on the students. This is also true of many survey-based studies as well, including those of Schmidt and his colleagues, where the focus is often on the effect of different facilitation approaches or types of faciltator (Schmidt & Moust, 2000).

Lycke (2002) conducted a study with nine problem-based learning teams with eight students and one tutor in each team. This study aimed at understanding how processes in PBL groups correspond with the theory-based intentions for PBL and to discuss the theoretical foundations for problem-based learning. Group activities such as brainstorming and the joint identification of learning issues as forms of cognition acquired through interactions in PBL classrooms were described in this study with a focus on improving facilitation rather than the student experience. The findings of this study indicated that groups followed a systematic step-wise progression and that students in groups become more flexible and self-directed in their use of PBL as they became more familiar with the approach, provided that the tutor did not dominate the interactions.

Although the observed processes reported in such studies support constructivist learning theories, and in turn problem based learning, it is important to note that these studies have analysed and described only isolated fragments of tutorials. A few studies go further to identify socio-cultural perspectives to knowledge construction, transformation and retention while participating in communities of practice (Hmelo & Lin, 2000). However, it is evident that such studies have not analysed and described the interaction of norms, attitudes, behaviours and learning approaches of students individually and as a team in PBL to investigate the impact of group processes on student learning in PBL teams (Evensen et al., 2001).

Another type of study explores how students respond to the PBL process. Some academic institutions prescribe a standard approach to PBL such as the "Seven-Jump" method to help students develop the process of learning by interacting with their PBL team members (Schmidt, 1993). However, Moust, Robertsen, Savelberg & Rijk (2005) found that as time passes by during the course, students become bored with the repetitious routine of working through problems using such prescribed procedures and omit important aspects of learning in PBL as a team. These include skipping the stage of elaboration of prior knowledge, reducing discussions to presentation of main results and making no attempts to appraise opinions and viewpoints or synthesise findings. They found that students avoid taking responsibility and an active part in discussions because of lack of interest, laziness, uncertainty or incompetence. Studies of this type provide another perspective on how students respond to PBL.

As noted above, many of these studies, whether survey-based or observational, concentrate on what happens in PBL tutorials and largely ignore what students do outside of tutorials. That is, nearly all papers focus on the classical PBL model of collaborative learning taking place in a facilitated group with everything else assumed to be individual self-directed learning. However, it is obvious that in the project-oriented model used in engineering, collaborative learning is also expected to occur outside of facilitated sessions, along with individual learning. In their review of research into factors affecting learning in PBL tutorials, Schmidt & Moust (2000) concluded that there has been little research into what students do outside of the formal tutorial meetings but they also noted that what little research there is suggests that many students do not do what was planned in the PBL tutorial.

All of the above suggests that our knowledge of PBL from a student perspective is limited, limited by the research approaches used, limited by the emphasis on facilitator practice and limited by an almost universal focus on the PBL tutorial. Hak & Macguire (2000) argued that studying what students do in PBL is pivotal to understanding the success of PBL programs in engaging students and in supporting deep learning. They argued that there is a need for further qualitative studies to provide a better understanding of how students perceive PBL and respond to PBL. It is for this purpose that this study sets out to investigate the learning cultures that emerge in PBL teams. It is expected that students' attitudes, behaviours and learning approaches individually and as a team will inform how they approach learning in a PBL team and how they achieve the desired learning outcomes. The findings of this study are expected to inform practitioners of PBL so that they may modify or improve their strategies to help their students establish productive learning cultures to achieve desired cognitive outcomes.

2.6 Disciplinarity and PBL

2.6.1 Disciplinary knowledge

The term discipline is used to describe types of knowledge, expertise, skills, people, projects, communities, problems, challenges, studies, inquiry, approaches, and research areas that are strongly associated with academic areas of study (academic disciplines) or areas of professional practice (profession) (Chettiparamb, 2007a). The term discipline can also be seen as a lens through which a phenomenon is examined. Each discipline affords the learner different viewpoints and a potentially different set of learning tools as well as subject matter material to be explored (Moss, Osborn, & Kaufman, 2008).

One impetus for the emergence of disciplines is the natural tendency of human beings to separate, classify and conceptualise the surroundings. For example, the phenomenon of gravitation is strongly associated with academic discipline of physics, and so gravitation is considered to be part of the disciplinary knowledge of physics (Chettiparamb 2007a).

However, the term ‘discipline’ is defined differently in different contexts. For example, within the engineering profession, the term ‘engineering discipline’ is often used to denote specialties such as electrical engineering, civil engineering and mechanical engineering. Within the discourse of curriculum development in higher education, on the other hand, the term often refers to the various academic disciplines that contribute to a course. In the case of engineering, this includes mathematics, basic sciences such as physics and chemistry, and engineering disciplines such as electronic engineering, electrical engineering, mechanical engineering, civil engineering, mining engineering and computer science engineering.

The notion of a discipline suggests boundaries around a body of knowledge. But these boundaries are, to a degree, arbitrary and many activities in real life necessarily cross these boundaries. For this reason, the emphasis in PBL on ‘real life’ professional problems means that crossing boundaries between academic disciplines is a characteristic of PBL. Many terms are used to describe when disciplines merge or the boundaries of existing disciplines are crossed. The most common are multi-disciplinary, inter-disciplinary, trans-disciplinary and cross-disciplinary.

2.6.2 Inter-disciplinary knowledge

Inter-disciplinary knowledge refers to new knowledge extensions that exist between or beyond existing academic disciplines or professions (Strathern, 2004). The new knowledge may be claimed by members of none, one, both or an emerging new academic discipline or profession, although it emerged as “bureaucratic shorthand” for research involving two or more professional societies (Chettiparamb, 2007b). Chettiparamb (2007b) also pointed out that the arguments for inter-disciplinarity comprise of two threads: normative; that is, filling the gap role of inter-disciplinarity, and phenomenological, which originated from observations of practice. She argued that inter-disciplinarity already exists within disciplines and quietly flourishes within.

In some jurisdictions, interdisciplinary curriculum is explicitly described. For example, The Victorian Curriculum and Assessment Authority, has developed and implemented a common curriculum standard called “Victorian Essential Learning Standards (VELS)” across all schools from Prep to Year 10 in Victoria, Australia (Victorian Curriculum and Assessment Authority., 2008). VELS consists of three core and interrelated strands for the Prep to Year 10 curriculum. Each strand has a number of domains which describe the essential knowledge, skills and behaviours students need to prepare for further education, work and life. The domains include the standards, organised by dimension, by which student achievement and progress is measured.

Inter-disciplinary learning is one of the three strands identified in VELS along with discipline-based learning and physical, personal and social learning. The domains of inter-disciplinary learning include learning communication; that is, listening, viewing, responding and presenting; design creativity and technology; that is, investigating, designing, producing, analysing and evaluating; information and communications technology; that is, ICT for visualising thinking, ICT for creating, ICT for communicating; and thinking processes; that is, reasoning, processing and inquiry, creativity, reflection, evaluation and meta-cognition.

2.6.3 Multi-disciplinary knowledge

Multi-disciplinary knowledge refers to the knowledge associated with more than one existing academic discipline or profession (Cupach & Spitzberg, 2004). People from different disciplines or professions work together in a multi-disciplinary team as equal stakeholders to address a common challenge (Fagin, 1995). However, Chettiparamb (2007b) notes that multi-disciplinarity may be seen as a juxtaposition of various disciplines, sometimes with no apparent connection between them, for example, music + mathematics + history.

2.6.4 Trans-disciplinary knowledge

Trans-disciplinary knowledge refers to knowledge that exists in every individual, thus eliminating the need for discipline boundaries. Trans-disciplinarity removes the notion that certain content matter is necessarily owned by any particular discipline. Trans-disciplinarity allows for viewing a problem from multiple perspectives and understanding it more fully than if it were observed from a single vantage point. This understanding inevitably leads to content learning and in the process of using the disciplines in the same ways that a discipline expert would use them to view the world, students and teachers learn the content that attracted subject-area scholars to the discipline in the first place (Moss et al., 2008).

2.6.5 Cross-disciplinary knowledge

Cross-disciplinary knowledge refers to knowledge that explains aspects of one discipline in terms of another. Common examples of cross-disciplinary approaches are studies of the physics of music or the politics of literature. The term "cross-disciplinarity" is frequently used in the psychology literature to describe any method, project or research activity that examines a subject outside the scope of its own discipline without co-operation or integration from other relevant disciplines (Strandburg & Raicu, 2006). It is clear that foreign methods of unrelated disciplines are used to benefit inquiry from the inclusion of other perspectives. Many research focus on the cultural impact of a discipline in the real world (Coiro, 2008; Tyler, 1994).

By this definition, cross-disciplinarity is distinctly different from inter-disciplinarity because of the relationship that the disciplines share. Within a cross-disciplinary relationship, disciplinary boundaries are crossed but no techniques or ideals are exchanged while inter-disciplinary relationships combine the practices and assumptions of each discipline involved. An example is the combination of media and politics.

Of these terms, cross-disciplinary is used very differently in different contexts, often being used as a synonym for multi-disciplinary or inter-disciplinary. For example, in the health professional education setting, cross-disciplinary learning is widely used for the clustering of inter-disciplinary perspectives on health, illness and medicine. This term is also used to represent the collaboration between specialities to pursue knowledge about complaints that are common or intertwined between two or more specialities (disciplines) for example, obstetrics and internal medicine. Occasionally, it also used to imply a blend of disciplines that are significant to the ethical practice of medicine including law, sociology, philosophy and psychology (Brannigan, 2001).

2.6.6 Cross-disciplinarity and Engineering

Integration in engineering has many facets, and can be expressed in many ways: the integration of engineering research and development, of design and manufacturing; the closer interplay of universities and industry; the greater exposure of engineering students to practical, hands-on, apprenticeship aspects of education. However, it is argued that the underlying theme can be narrowed down to the need for a new cross-disciplinary approach to solve complex engineering problems as long-established individual disciplines of engineering such as civil, mechanical, electrical alone are not always suited to the complex nature of the problem (Cross-disciplinary Engineering Research Committee, 1986).

In the engineering literature, cross-disciplinarity is also used when referring to a systems approach or systems thinking. A systems approach to problem-solving refers not just to systems engineering, but to the need for attention to the systems aspects of the engineering enterprise and its products, and for optimizing the overall process by considering every element, looking for tradeoffs, incorporating diverse kinds of expertise, taking the broadest possible view (Skyttner, 1996). This not only suggests an understanding of other engineering disciplines but an understanding of disciplines outside of engineering so that the socio-political context of the problem is appreciated.

2.6.7 Conditions that help fostering cross-disciplinary learning

It is often claimed in the PBL literature that PBL develops cross-disciplinary knowledge that helps professionals expand their scope of knowledge and skills beyond the confines of their own professional disciplines (Streichert et al., 2005). It is claimed that knowledge of cross-disciplinary resources and learning to apply cross-disciplinary skills help to enhance preparedness to approach ideas or methods from other disciplines in difficult and often unusual situations. The notion of discipline here is that of the engineering discipline or specialty rather than the academic discipline.

A common idea that emerges from the literature of cross-disciplinarity is seeing beyond what appears to be isolated and independent problems or incidents to gain a deeper and holistic understanding. Biggs (2003) noted this as functioning knowledge, which is within the experience of a learner who integrates declarative, procedural and conditional knowledge to solve problems, design buildings or perform surgery.

PBL in engineering, on the other hand, has the potential to integrate disciplines in several ways. PBL problems often require the integration of several academic disciplines so they are cross-disciplinary in the academic sense. PBL can also support the development of the functioning knowledge referred to above by putting academic declarative knowledge to work. PBL can also require a consideration of the socio-political context of problems, so it may be cross-disciplinary in the sense of incorporating disciplines outside of engineering. Finally, PBL problems in engineering may involve more than one engineering discipline or specialty so they may cross boundaries in this sense.

The challenge for PBL designers and PBL practitioners is to realise this potential. The PBL literature is limited in terms of specific guidance in this area. How can we design a curriculum that encourages students to integrate academic disciplines? How can we design a curriculum that encourages students to put their academic knowledge to work? How can we convince students that an understanding of the socio-political context is essential for engineers? How can we foster cross-disciplinary conversations among students especially when they have already decided their speciality?

There are some very general answers to questions such as these. Most approaches that emphasise cross-disciplinary learning are based on active learning strategies and are designed to promote higher-order creative and critical thinking skills. These strategies include collaborative and co-operative learning (Hmelo-Silver, 2002), creative learning, inventive learning (Tornkvist, 1998), reflective learning (Uden & Beaumont, 2006), writing and mathematics across the curriculum, transformative learning (Schoner, Gorbet, Taylor, & Spencer, 2007) and methods of assessment that are multi-dimensional, including quantitative and qualitative measures, normed measures and self assessments (University of New South Wales, 2007).

A legendary approach suggested to manage knowledge across disciplines is to cultivate a community of practice (Lave & Wenger, 1991; Wenger, McDermott, & Snyder, 2002). The use of information and communication technology is also encouraged to enhance learner interactions across disciplines (Wenger, Huysman, & Wulf, 2003).

Many universities in Australia and around the world have started to adopt a common first year model in engineering to foster cross-disciplinary learning. As students learn about a range of disciplines and not just specialise in one area, they become exposed to the breadth of engineering as well as the application of engineering in servicing the community.

A problem-based or project-based approach can support cross-disciplinary learning along with the development of a strong disciplinary knowledge base. However, it depends on the use of problems to create a situation where students must confront and resolve real, cross-disciplinary situations. If the solution path is not immediately obvious and the disciplinary domains that might be applicable are not within a single domain students will tend to broaden their perspective and liberate creative ideas while working on the problem (OECD, 2003).

2.7 Creativity, innovative thinking and PBL

Innovative thinking has been studied in a variety of contexts, including in relation to technology, commerce, social systems, economic development, and policy construction. Innovators change the world by stepping into the "intersection," a place where ideas from different fields and cultures meet and collide, ultimately igniting an explosion of extraordinary new discoveries (Johansson, 2004). Johansson calls this proliferation of new ideas "the Medici effect" - referring to the remarkable burst of creativity enabled by the Medici banking family during the Renaissance in Italy. He reveals how intersections can be identified in our own lives and how we could turn the ideas we find there into "path-breaking" innovations. Johansson (2004) illustrates how three driving forces - the movement of people, the convergence of scientific disciplines, and the leap in computational power - are increasing the number and types of intersections we can access.

Evidently, there are many approaches to conceptualise innovation in the scholarly literature. Fortunately, however, a consistent theme may be identified: innovation is typically understood as the successful introduction of something new and useful, for example introducing new methods, techniques, or practices or new or altered products and services that are widely used (I. Miles, 2005). It is argued that all innovations begin as creative solutions. But, not all creative solutions become innovations because they are not widely adopted. Some innovations also qualify as inventions (Fobes, 2002).

2.7.1 Creative problem-solving

Creative problem-solving is defined as seeking original ways to reach a goal when the means to do so are not readily apparent or previously established. It is also seen as ranging from a short and simple activity to a long and complex activity because of its different stages, causes and uses (Treffinger & Isaksen, 2005; Treffinger & McEwen, 1993). Some aspects of creative problem-solving include creative skills (emerging from divergent and critical thinking), creative approaches (emerging from developing new ways and changing the known or producing novelty) and creative products (emerging from a novel solution or many novel solutions and drawing appropriate conclusions that lead to a solution to the problem) (Cropley, 2001c).

Creative problem-solving is linked to both creative and critical thinking. Although creative and critical thinking are seen as incompatible and opposites, Treffinger and Isaksen (2005) viewed them as two complementary mutually important ways of thinking. Creative problem-solving process involves two stages, which are ‘generating’ and ‘focusing’ thoughts. The generating stage involves creative thinking. In this stage gaps, paradoxes, opportunities, challenges or concerns are encountered resulting in a search for meaningful new connections. The focusing stage involves critical thinking. In this stage possibilities are examined carefully, fairly and constructively and then the thoughts and actions are synthesised by organising and analysing possibilities, ranking and prioritising options and then choosing and deciding on certain options (Treffinger & Isaksen, 2005).

Creative thinking is often described as a divergent process, which begins at a single point or a single question, but extends in different directions generating a wide variety of new possibilities. Critical thinking is often called convergent thinking, which is the process of attempting to take many different ideas and draw them together towards a single goal or a result (Hudson, 1970a, 1970b).

2.7.2 Creativity

Although creativity (a product of creative thinking) has a long history, systematic study of creativity began in 1869. Craft (2001) highlighted that Galton (1869) undertook a study that focussed on the idea of ‘genius’. Creativity was subject to philosophical speculation in the early twentieth century because of the methodological approaches of the traditions in which it was studied. In the psychoanalytic tradition, creativity was seen as the sublimation of drives, which makes it central and intrinsic to human nature. In the cognitive tradition creativity is seen as exploration of divergent production of ideas and products. In the behaviourist tradition, stemming from Skinner's discussion of chance mutation, creativity is seen as the repertoire of behaviours. In the humanistic tradition, discussions about creativity focussed on the self-realising person acting in harmony with their inner needs and potentialities (Craft, 2001).

A move towards empirical investigation of creativity took place during the 1950s. Empirical work formed the methodological basis for much of the investigative work during this period and researchers focussed on the psychological determinants of individual genius and giftedness (Guilford, 1950). This research led to three major lines of development: work on personality, cognition and how to stimulate creativity. The role of thinking in creativity, the role of personality traits and the strategies that promote creativity are widely discussed in the literature (Craft, 2001; Cropley, 2001b, 2001d).

The 'classical' analysis of the emergence of creative products is the phase model, first introduced into creativity research by Wallas in 1926. In his study "The art of thought" creativity was described as a problem-solving capacity and distinguished it into four phases or stages. In the first phase, referred to as the phase of information, a person becomes thoroughly familiar with a content area. In the incubation phase, the person 'churns through' or 'stews over' the information obtained in the previous phase. The phase of illumination marked by the emergence of a solution, not infrequently seeming to the person involved to come like a bolt from the blue. Finally comes the phase of verification in which the person tests the solution thrown up in the phases of incubation and illumination (Wallas, 1926).

Empirical studies of the process of creation in people actually engaged in something new, as well as retrospective studies in which acknowledged creators describe how they obtained new ideas have cast doubt on the validity of the phase model (Torrance, Glover, Ronning, & Reynolds, 1989). Such studies have helped to untangle the paradox of creativity.

In the 1990s research into creativity became rooted in a social psychological framework which recognises the important role of social structures in fostering individual creativity. Studies that see creativity from a systems perspective emphasise various elements of social and cognitive contexts that are seen as highly relevant to the activity of creating (Csikszentmihalyi, 1996; Gardner, Goleman, Csikszentmihalyi, & Salovey, 1998).

Slade (1992) quoted Vygotsky and argued that it is possible for children to think at far higher levels in a group than they would be able to alone. She argued that interaction or dialogue allows development of capacities which students could not achieve in isolation. She also argued that in terms of teacher-student relations, the teacher's role is to anticipate and provide structures to aid development and thereby scaffold learning. She deemed that the community of enquiry can be seen as a scaffolding device, in which the teacher increasingly hands over the scaffolding techniques to the student themselves and thus promotes creative and critical thinking.

Csikszentmihalyi (1996) emphasised the importance of socio-cultural validation and indicated the need to take account both of communication and novelty for other people and also of their assessment of its effectiveness. In an attempt to incorporate a socio-cultural perspective, Cropley (2001) modified Wallas' four phase creative problem-solving process by introducing three more stages namely the communication and the validation stages after the verification stage, and the preparation stage before information stage. The creative processes, traits and the phases of production of novelty as indicated by Cropley (2001) are shown in the following Table 2.2.

Table 2.2 Creative processes, traits and motives in the phases of production of novelty (Cropley, 2001b, p. 73).

Phase	Process	Result	Motivation	Personality	Feelings
Preparation	• Identifying problem • Goal setting • Convergent thinking	• Initial activity • General knowledge • Special knowledge	• Problem solving drive (intrinsic) • Hope of gain (extrinsic)	• Critical attitude • Optimism	• Dissatisfaction
Information	• Perceiving • Learning • Remembering • Convergent thinking	• Focussed special knowledge • Rich supply of cognitive elements	• Curiosity • Preference for complexity • Willingness to work hard • Hope of gain	• Knowledgeability • Willingness to judge and select	• Interest • Curiosity
Incubation	• Divergent thinking • Making associations • Bisociating • Building networks	• Configurations	• Freedom from constraints • Tolerance for ambiguity	• Relaxedness • Acceptance of fantasy • Non-conformity • Adventurousness	• Determination • Fascination
Illumination	• Recognising a promising new configuration	• Novel configuration	• Intuition • Reduction of tension	• Sensitivity • Openness • flexibility	• Excitement
Verification	• Checking relevance and effectiveness of novel configuration	• Appropriate solution displaying relevance and effectiveness	• Desire for closure • Desire to achieve quality	• Hard-nosed sense of reality • Self-criticism	• Satisfaction • Pride in oneself
Communication	• Achieving closure • Gaining feedback	• Workable product capable of being made known to others	• Desire for recognition (intrinsic) • Desire for acclaim or reward (extrinsic)	• Hard-nosed sense of reality • Self-criticism	• Satisfaction • Pride in oneself
Validation	• Judging relevance and effectiveness	• Product acclaimed by relevant judge (e.g. teacher)	• Desire for acclaim • Mastery drive	• Toughness • Flexibility	• Elation

2.7.3 Engineering, creative thinking and PBL

Smith-Bingham (2006) argues that there are social and cultural elements that contribute to the consideration of creativity as a prized asset that stimulates innovation. Creativity is a key resource for individuals and societies that will enable us to make the most out of new opportunities, and to find the most productive response to challenges and threats. Most countries around the world share similar sentiment which underpins strategies that help build a dynamic, competitive, knowledge-based economy. Global resonance for innovation is focussed towards the speed at which the consumer demands and tastes are changing, and the increasing developments in technology and scientific understanding.

Creativity is increasingly being recognised as an essential attribute for engineers. In an engineering workplace, engineers are constantly presented with challenging problems that requires the use of new ideas, critical and creative thinking. The American Engineers' Council for Professional Development defines engineering as:

> "The creative application of scientific principles to design or develop structures, machines, apparatus, or manufacturing processes, or works utilizing them singly or in combination; or to construct or operate the same with full cognizance of their design; or to forecast their behaviour under specific operating conditions; all as respects an intended function, economics of operation and safety to life and property (ScienceDaily, 2008)".

This also applies in Australia. Engineers Australia (Retrieved 13th May, 2005, p. 5) defines capacity for creativity and innovation under professional attributes in its Stage 1 competency requirements. The elements of this competency include:

- Readiness to challenge engineering practices from technical and non-technical viewpoints, to identify opportunities for improvement;
- Ability to apply creative approaches to identify and develop alternative concepts and procedures;
- Awareness of other fields of engineering and technology with which interfaces may develop, and openness to such interactions;
- Propensity to seek out, comprehend and apply new information, from wide range of sources;

- Readiness to engage in wide-ranging exchanges of ideas, and receptiveness to change (Engineers Australia, 2005).

Engineering educators are therefore also turning their attention to developing the creativity of their students.

2.7.4 Conditions that help foster creativity

In a recent radio interview, the President of Olin College in the USA argued that most school leavers who enter engineering degree courses often make their decision based on the grades that they obtained in mathematics and science and most of them do not realise that engineers are expected to work in teams and create innovative solutions to problems (ABC, 2008). Olin College therefore emphasises the development of creative thinking in its students by allowing them to undertake passionate pursuits (Kerns et al., 2006).

Most programs that foster creative thinking emphasise taking a holistic approach (Cropley, 2001a). While many techniques are recommended to help students generate new ideas, the most popular approach that is found in literature is the “brainstorming” technique (Osborn, 1963). Optimal brainstorming sessions allow for 15-20 minutes of individual thinking time and for participants to present their ideas to their facilitator anonymously on a piece of paper. All ideas are then openly discussed and in that process students are taught to withhold their judgement. Thus, the most common approach of seeking to criticise an idea or a process to argue why an ideas or process would not work is eliminated (Johansson, 2004; Osborn, 1963).

However, some studies suggest that due to evaluation apprehension and blocking, group creative problem-solving efforts involving brainstorming often led to the generation of fewer ideas in groups when compared to the ideas that were generated by participants in isolation (Borphy, 2006; Johansson, 2004). Other identified causes of failure to generate ideas include perceptual sets, conformity pressure, social loafing, distractions and members wasting time waiting to speak (Borphy, 2006).

Collaboration is important for achieving creative outcomes in teams. Group success depends on team members being motivated to contribute what they can. When team members are encouraged to co-operate (share resources and outcomes) with each other, competition between team members is eliminated (Borphy, 2006).

Problem-based approaches are often advocated to promote creative thinking in classrooms (Barell, 2005; Hamza & Griffith, 2006; Treffinger & McEwen, 1993). Despite this, there is little research into the integration of creative problem-solving with PBL. Studies conducted by Lumsdaine, Lumsdaine and Shelnutt (1999) and Treffinger and Isaksen (1994) are notable exceptions. Although there is a strong focus in many PBL programs on developing innovative thinking, teamwork, and communications in response to the needs of industry, there is scant empirical evidence to corroborate that PBL indeed promotes the learning of innovative thinking skills (Conway & Wynder, 2001). The study reported in this thesis is designed to make a contribution to this research area.

2.8 Summary and conclusion

The literature on PBL is both extensive and incomplete. It resembles a big jigsaw puzzle with hypotheses, theoretical frameworks and premonitions drawn from the vast body of knowledge which is the literature on learning itself. In spite of the breadth of literature there are gaps in the puzzle that remains unfilled, unassembled. This could possibly be because of the very nature of the approach; existing problems in PBL and the way it is implemented in particular disciplines.

Problem-based learning has proved to be both contentious and pervasive in health professional education settings. Its introduction typically challenges institutions, educators and learners to reflect critically on their educational philosophy and their educational priorities (Schwartz, Mennin, & Webb, 2001). However, many have criticised the existing literature and suggested improvements. For example, Pintrich (2000) contended that there is a clear need for more descriptive, ethnographic and observational research on how different features of the context can shape, facilitate and constrain self-regulated learning. Kelson (2000) noted the contradiction that self-directed learning is identified simultaneously as an assumption and an outcome of PBL curriculum and suggested that this be investigated. Van der Vleuten and Schuwirth (2004) identified the need for more qualitative studies that build theory, focusing on direct validity or educational impact particularly concerning research in assessment.

Constructivist pedagogies are becoming part of engineering education courses. Expectations have emerged from the industrial world where knowledge is seen as created rather than received (Holt-Reynolds, 2000), mediated by discourse rather than transferred by lectures (Vygotski, 1962), explored and transformed rather than remembered as a set of positivistic ideas (Dewey, 1969). Public awareness of what engineers are and how they significantly contribute to the community in general has resulted in closer scrutiny of engineering education.

Consequently, most engineering educators no longer see dispensing knowledge as sufficient to educate engineers. Teachers are asked to encourage active student participation and to use students' existing ideas as a basis to construct new disciplinary and cross-disciplinary understandings. Teachers are asked to facilitate student learning by actively engaging their participation and using that as a context to liberate students' thinking.

On the other hand, the engineering industry expects students to be business-ready as well as work-ready. They expect students to possess high level innovative and creative skills. They expect students to work at clock speed and not at calendar speed. It is interesting to note that some engineering educators have called for further research into staff engagement and student engagement in order to restructure, refocus and rationalise educational methods. They call for a fundamental change in the culture of learning in engineering schools (Singh, 2006).

Many questions remain regarding the effectiveness of PBL; but two key questions are 'What do students learn?' and 'How do they respond to the system?' There are different perspectives from which these questions have been approached (Nisbet et al., 2005). These include an institutional perspective with a focus on administrative and resource issues (Bridges, 1992), a teacher's perspective with a focus on what students learn, changing content and staff development and a student perspective with a focus on dysfunctional groups (Dolmans, Wolfhagen, & Vleuten, 2001), absence in PBL sessions and meetings (Kaufman & Mann, 2001), and reactions to the change in learning system (Cita & Van, 1997).

While there is an established literature on what students learn in PBL (Hmelo-Silver, 2004; Savin-Baden, 2000; Strobel & Barneveld, 2008), there are fewer studies that explore how students function as part of a PBL team. Hence, in the current study, the main focus is on the experience of engineering students in the PBL process and its effects on their learning. The shift to PBL represents a shift from teacher-centred to learner-centred education. It also assumes a shift from independent learning to collaborative learning. This study therefore focuses, in part, on student responses to this shift in emphasis.

The existing engineering curriculum at most Australian universities already engages its students in traditional problem-solving. The introduction of PBL is expected to extend this by emphasising cross-disciplinary learning and helping students gain both generic skills and technical knowledge and skills. This learner-centred approach hopes to help students to strengthen and emphasize the importance of the discipline as a whole and the interdependence of its parts in other areas (Kaufman & Mann, 2001).

PBL is expected to equip students with the confidence, life skills and learning skills that they often lack on entry, while enhancing their engagement and encouraging deep approaches to learning in their technical subjects throughout the program. It is planned that students will systematically develop the communication, problem-solving, and teamwork skills that are vital for employment in modern industry (Victoria University, 2005). It is claimed that PBL will also provide students with experience in cross-functional skills and substantially reduce teaching efforts in later years of the program as students take responsibility for their own learning (Nisbet et al., 2005), thereby ensuring every student's capability and motivation for life long learning (Dempsey, 2002).

In conclusion, the present study aims to investigate a PBL curriculum from the students' viewpoint. It will explore the learning cultures that developed as the students participated in an engineering PBL program. As might be expected, the learning cultures reflected the heterogeneity of the students and their different responses to being given more responsibility for learning in this type of curriculum. This study will identify, explore and report on the factors that impinged on or encouraged student learning behaviour and attitudes towards learning in their first year of an undergraduate engineering course. Studying the learning cultures that developed in

PBL teams was designed to provide evidence to further theorize about the models of self-regulation in autonomous learners (Nisbet et al., 2005). This study also examines the influence of the learning cultures that developed in this PBL environment on learning outcomes, in particular those relating to cross-disciplinary learning and creativity. The intent overall is to provide evidence that may prove useful in improving the quality of teaching or enhancing the curriculum. In the following chapter, the research questions of interest, the research design and the research methodology that were used to conduct this study will be presented and explained.

Chapter 3

Research design and methodology

3.1 Introduction

This chapter provides details of the systematic approach to the research process that was used for this study. This chapter is divided into three sections. The research aims and the research questions are presented in the first section. The second section includes detailed explanation of the research methodology used in this study and a rationale for using such an approach for collecting data. This section also contains a description of the methods used to collect data for this study and the methods used for data analysis. All research procedures reported in this thesis were approved by the University Human Ethics Committee, Victoria University. The credibility of the study is discussed in the last section of this chapter where the validation methods to confirm the integrity of data analysis are presented.

3.2 Research aims and research questions

At the time of commencement of this study, the literature review revealed that there is limited substantial research that examines the different learning cultures that may emerge in an engineering PBL setting. The PBL literature concerned with, for example, health professional education setting, indicate that the strategies and processes adopted by students to direct and approach their learning as a team influence their learning in a PBL setting (Evensen & Hmelo, 2000; Evensen et al., 2001; Hmelo-Silver, 2004). However, this idea has not been approached from the perspective of students in a multicultural Australian higher education setting. The literature review also identified a need for more descriptive, naturalistic approaches that theorise models of the development of autonomous learners (Nisbet et al., 2005).

Hence, the role of first year electrical engineering students in the PBL process and its effects on their learning, as well as the different learning cultures that developed in small student groups working as a team in engineering PBL settings will be the main focus of this study (Neal, 2005; Vale, 2001). The shift to PBL represents a shift from teacher-centred to learner-centred education. This study therefore focuses on student responses to this shift in emphasis in a newly implemented PBL curriculum and setting. It was expected that the learning culture would reflect the heterogeneity of the students and the different responses of the students to being given more responsibility for their learning (Le Cornu & Peters, 2007).

The broad research question for this focus, therefore, concerns the learning cultures that emerge in problem-based learning teams. The contributing research questions to assist this enquiry concern the participation of students in PBL teams, student approaches to learning as individuals and as a team, and the strategies and processes they used to direct their learning both as individuals and as a team.

RQ 1: What are the learning cultures in problem-based engineering curriculum?

- How do students from diverse educational, linguistic, ethnic and religious backgrounds participate in the context?
- How do the students approach learning?
- How do the students control, regulate and direct their learning?

It is expected that the analysis of the learner environment in engineering PBL curriculum, presented as narratives of individuals, teams and events will have a quality of un-deniability and provide a concrete vivid meaningful flavour (Denzin & Lincoln, 2003).

The other two broad research questions for this study are:

RQ 2: In what ways does PBL support both cross-disciplinary learning and the building of a strong disciplinary knowledge base?

RQ 3: In what ways does PBL promote innovative thinking?

These questions are pursued in this study because it was found from the review of the literature that PBL is purported to help students construct an extensive and flexible knowledge base which extends beyond learning the facts of a domain, integrates information across multiple domains and provides opportunities for developing innovative thinking capabilities (Barrows & Kelson, 1995). Hence, this research study seeks to confirm these claims through the investigation of the learning of students in a newly implemented PBL curriculum and setting.

It is also expected that investigating the learning of individuals in this PBL setting may help identify the factors that contribute to the success of their teams. This, in turn, may provide evidence of how well the PBL environment created for these students lived up to other claims made for problem-based learning, including encouraging learning across disciplinary boundaries and improving their capability for innovative thinking in solving engineering problems.

From the literature review, it was found that student learning in a PBL setting is likely to be influenced by several factors. While the social make-up of a team exerts influence on the attitudes and behaviours of students in that team, other factors such as teacher directions and expectations, expected learning outcomes, the nature of the problem and assessment also appear to influence student learning (Barnes, 2005; Dunlap, 2005). The membership of a PBL team, patterns of communication between team members, the nature of student engagement in their team and the group processes and approaches to problem-solving adopted by PBL teams all seems to be important factors and are considered in this study.

3.3 Research design and methodology

Since the focus of this research was to explore, describe and interpret the approaches of individual students to learning, the learning cultures adopted by student teams and some general learning outcomes, an ethnographic methodology was used. This section provides a rationale for using an ethnographic approach and an explanation of the data collection and analysis methods used for this study.

My extended contact with the engineering community as an electronics and communication engineer and then as an engineering teacher at Victoria University prompted me to investigate student learning in higher education engineering settings. As Victoria University was currently transforming its undergraduate engineering courses from lecture-based education to problem-based learning, it provided a suitable location for conducting this research study.

Undergraduate engineering education involves a gradual transformation from being a student in the engineering classrooms to a fully-fledged engineer. I believe that realities of such a transformation are situated in the context and cannot be isolated from the context. Moreover, literature suggests that learning acquired through PBL is a classic example of situated learning (Brown et al., 1989). This recognises that student learning in a PBL setting involves more than merely being taught, but is an active collaborative process situated in communities of practice (Lave & Wenger, 1990). The theory of situated learning underpins a lot of thinking concerning collaborative learning in teams and professional development, which in turn informs the way we think about student learning in PBL teams.

Mixed methods and qualitative methodologies are most prominent among researchers who focus on situational perspectives in higher education. Research takes place in situ and reflects on assumptions that knowledge is constructed within specific contexts which have specific situational affordances; that is, the relationship between learners and the properties of specific environments.

While experts claim that quantitative methods are better than qualitative methods and vice-versa, it is only when we step back from these arguments and scratch beneath the surface, we come to realise the relative benefits of these methods. In qualitative studies, methods used are varied but the focus is often on the increased participation in specific communities of practice, the relationship between learners and the properties of specific environments and the distributed nature of knowing in specific communities. A major feature of quantitative methods used in situated cognition is the absence of outcome measures (Hak & Maguire, 2000). Quantitative variables used in mixed methods often focus on process over product. For example trace nodes, dribble files, and hyperlink pathways are often used to track how students interact in the environment (Shaw, Effken, Fajen, Garrett, & Morris, 1997).

The focus of this research was to study student learning approaches and their cognitive and social interactions in PBL teams that influenced their team learning cultures and their learning outcomes. Therefore, I decided to approach this investigation by using a naturalistic approach (Lincoln & Guba, 1985) that involved living with the student tribe for the entire duration of the data collection. Therefore, I decided to approach this investigation by using a naturalistic approach (Lincoln & Guba, 1985) that involved living with the student tribe for the entire duration of the data collection.

The methodology for this research study was chosen to suit the research questions and to enrich the notion of learning cultures that emerge in PBL teams. The concept of learning culture that emerges in a PBL team as a result of the interactions of norms, attitudes behaviours and learning approaches of its members is considered the nature of reality (ontology). As this study is set to investigate a constructivist paradigm, the overarching research strategy employed that is qualitative naturalistic inquiry will inform its epistemology - the nature of this knowledge, its foundations, scope and validity.

Most qualitative research studies that use naturalistic approaches such as participant observations to collect data use ethnography, a genre of writing, to provide descriptive accounts of people, their beliefs and behaviours from their perspective of a context (Bogden & Biklen, 1998; M. B. Miles & Huberman, 1994; Vale, 2001). This is particularly because of its remarkable sensitivity to people, culture and context to observe, interview and accumulate field notes and other materials (M. B. Miles & Huberman, 1994). Further, as ethnographic research is conducted in the natural setting, it allows selecting or sampling of groups or individuals for the study because they display characteristics that are considered to be archetypal of the group or the phenomenon under consideration (Vale, 2001).

Hence, after carefully considering many important issues such as time and effort involved, the type of data collection involved (observation, interviews, etc.) and the anonymity of the participants, it was decided that this research study would use the advantages of ethnography to study the experiences of students and their teams in PBL. As this study focuses on student experiences of PBL from their view point, it was important to observe students in their learning spaces rather than just conducting interviews. Ethnographic observation not only adds richness to the collected data, but also provides privileged insight into student attitudes and behaviours towards autonomous learning and learning in a team.

3.3.1 Participants and sampling procedures

This study was conducted at the School of Electrical Engineering at Victoria University. It is recalled here that all research procedures reported in this thesis were approved by the University Human Ethics Committee, Victoria University. Students studying the PBL subjects or units of study in a first year electrical engineering degree were invited to participate in this study. This School along with the School of Architecture, Mechanical and Civil Engineering designed and implemented problem-based curricula for the first time at the time this study commenced. Further details about the course and the PBL subjects are provided in Chapter 4.

Of the 79 first-year students who were initially enrolled in the electrical engineering degree, 50 students agreed to participate in this study. Students and their PBL supervisors were observed after seeking permission from all of them to participate in observations of students in various PBL settings for example, in their PBL classroom, at the electronic engineering laboratory and at the university library. Informal interviews were conducted with the first year electrical engineering students and their teachers who provided permission for observation. A total of eight supervisors participated in this study during observation of students.

Special permission was sought from ten students selected at random for formal interviews, access to the samples of their work and for observing their participation in a simulated engineering problem-solving situation. The study was conducted over two semesters for one year and followed the same students. One of the ten randomly selected student subjects in this study discontinued the course after Semester 1. The data concerning this student was discarded. Another randomly selected student subject, who was frequently absent, indicated a desire to withdraw from formal interviews during Semester 2 citing unavailability as his reason. However, this student permitted the use of data involving his participation collected during Semester 1. This reduced the total number of randomly selected students for the non-naturalistic aspects of this study to eight in Semester 2.

3.3.2 Role of the researcher

For the entire duration of this study, I presented myself to the participants of this study as an observer. I neither taught nor assessed students in the PBL program. Some interactions with participants were expected to occur informally with students during observations in their PBL workspaces (studios). In order to avoid risks such as, students who may be concerned that I may divulge comments made by them to the PBL supervisors, all participants were informed and reminded that I was not a teacher or a teacher's spy and that I would not direct, instruct or help them do their work. They were also informed that any form of information involving them would not be shared or passed on to their supervisors unless they explicitly asked for that to happen.

Participant teacher subjects, who may have been concerned that I might divulge comments made by them to the institution were also informed and reminded that the data collected in the study would not be used as a measure of their performance. They were informed and reminded that I was not a spy for the institution and any information concerning them would not be passed on to the institution.

I negotiated times suitable to students for observation and interviews. This indicates the fact that I was not present all the time. Participants were reminded that they could withdraw at anytime; leave at anytime and any data involving the individual who did not wish to participate further would be discarded if they wished.

As an observer in this PBL setting, I was exposed to student opinions about the PBL problems that they were given during their course and their concerns regarding the level of complexity, the time duration that they thought was required to solve those problems and access to the resources that they thought were required. This knowledge of student views of a problem in PBL helped me to design the problem for the simulated problem-solving activity. My role as an observer also helped me organise my ideas for analysing the data, although multiple methods were used for collecting data for this study. The data collection methods used for this study will be explained in the following subsection.

3.3.3 Data collection

Approaches to data collection in qualitative research continually expand in order to provide more instances and thereby enhance research designs (Bogden & Biklen, 1998; M. B. Miles & Huberman, 1994, 2002). According to Miles and Huberman (1994), information may be collected using four basic types for all the traditions in qualitative research including ethnography. They are observations, interviews, documents and audio-visual materials. The processes that enable these data collection methods include gaining access and establishing rapport with the participants (in this case the students as well as their PBL supervisors), recording information, exploring field issues and storing data for analysis (Creswell, 1998).

This research study used all four types of data collection methods: observations, interviews, document reviews and audio-visual materials. Data was collected in this study over two semesters. Data collection started at the beginning of Semester 1, 2006 and finished at the end of Semester 2, 2006.

3.3.3.1 Observation

Ethnography was the preferred method for observing the students, their attitudes, behaviours and interactions as individuals and as a team to interpret their learning approaches, learning cultures and their learning outcomes in the engineering PBL setting. The observation methods that were used in this study were trialled in another tertiary group problem-solving setting unrelated to the engineering program before observing the participants of this study. The trial provided an opportunity to strengthen the focus and the guiding questions that were used for this study.

Observations of students in this study were carried out in two contexts. Firstly, observations were carried out when the randomly selected students participated in scheduled supervised team meetings for one hour every week during both Semester 1 and Semester 2. Secondly, observations were carried out with all student participants when they met unsupervised in the PBL studios and elsewhere, for example at the electronics laboratory, the university cafeteria, the university bar and in the corridor next to the PBL studios where students conducted some of their experiments. Students in some teams had unsupervised meetings more than once a week and students in some other teams met only during supervised team meetings. At least six observations were carried out every week during both Semester 1 and Semester 2.

All the observations were recorded by taking field notes. These included descriptive and reflective notes, which are rich and thick descriptions of observations based on an observation protocol or log (Creswell, 1998). A log is a predetermined protocol that contains the research questions to focus the observations. Some examples of questions that were used as a guide to focus observations included:

- Who is present in the team?
- Who initiates the conversation in the team?
- What is the team currently discussing?

- What activities are students involved in?
- What are the different roles that students assume?
- How do they respond to their supervisor's directions?
- Who leads the team?
- How do students communicate with their peers?
- What ideas are exchanged during such conversations?
- What is the role of teachers?

A sample of the field notes taken during observation of a supervised team meeting is presented in Appendix 1. In addition, some team meetings and team oral progress presentations were video-recorded. According to Denzin and Lincoln (2003), video-recording can clearly define the sense of complexity and can assist construction of interpretations that build on the researcher's notion and assist revisiting. It is for the same purpose that video-recording was used in this study. All video recordings were transcribed and the transcripts were used for analysis. A sample of the transcript of video-recorded observation of a supervised team meeting is presented in Appendix 2.

3.3.3.2 Interview

Alongside ethnographic observations, semi-structured individual student interviews of 20 minutes' duration and student focus group interviews of 30 minutes' duration were conducted to support and complement the data collected through observations. The individual interviews and focus group interviews conducted are called 'formal interviews' in this dissertation. Twenty eight formal interviews were conducted with randomly selected students in this study. Other participants were not formally interviewed. Focus group interviews were conducted at the beginning and individual interviews were conducted at the end of both Semester 1 and 2.

Open-ended questions that required participants to provide an elaborate answer about their experience in PBL rather than answering 'yes' or 'no' were designed for both focus group and the individual interviews. The questions for focus group interviews focussed on how students approached learning as a team in PBL and the questions for individual interviews focussed on their individual contributions and engagement in team-work. Questions about their understanding of learning in PBL and their learning outcomes were also included in the individual interviews. The focus group interview questions for Semester 1 and 2 and the individual interview questions for Semesters 1 and 2 are presented in Appendix 3 and 4 respectively.

All formal interviews were conducted at a time that was convenient for the participants. All formal interviews were audio-recorded along with notes taken while interviewing participants.

In addition to the formal interviews, informal interviews were conducted with the general cohort of first year students studying in PBL. Informal interviews were conducted during observations and at other times when students socialised at the university bar. Informal interviews were also conducted at a student participant's birthday party to which I was invited. The questions asked in informal interviews were mostly designed to clarify a student's conversation, action or behaviour during an unsupervised team meeting or at the laboratory. Examples of informal interview questions included:

- Where did you get this circuit diagram from?
- Why are you using a Zener diode?
- What is different in this design when compared to your previous design?

Sometimes informal interview questions such as "What are you guys up to?" were asked to understand rather than assume the activities in which students were involved at the time of beginning both formal and informal observations. Creswell (1998) insisted that data collected from multiple sources and informal conversations should be written immediately to prevent loss of information. Informal interviews in this study were not audio-recorded, but were immediately written down on paper. Some informal interviews were video-recorded as questions were sometimes asked during the middle of video-recording a team meeting.

3.3.3.3 Course documents

The course documents are a source of information that direct student learning. As course documents may define the learning objectives, the expected learning outcomes and learning activities including the problems and approaches that students are required to use for their course, these documents were collected for this study. Course documents collected for this study included the course brochure for the Bachelor of Electrical and Electronic Engineering degree, unit outline for the two PBL units in the first year, problem briefs, the induction manual, course timetables and PBL studio timetables. The course documents were available to all students studying the PBL subjects and were mostly collected from the University's internet website. Problem briefs were collected at the time they were provided to students. The problem documents that were collected for this study are presented in Appendix 5 and are analysed in Chapter 4 to explore the setting in which this study was conducted.

3.3.3.4 Student work samples

The samples of student work used in this study were their portfolios. Individual portfolios were the main form of assessment for each of the PBL subjects. The student portfolio was essentially a collation of evidence for that student's achievement of each of the prescribed learning outcomes for that subject. The portfolios of the ten randomly selected students were collected after they had been formally assessed by their PBL supervisors in the end of Semester 1. However, only eight portfolios were collected in the end of Semester 2, because two students could not be followed in Semester 2 for the reasons mentioned earlier.

It was expected that the portfolios would illustrate what students had actually learnt in the PBL subjects. Student portfolios were also used to look for evidence of student application of disciplinary and cross-disciplinary knowledge and of innovative skills. Sample data from students' portfolios are presented in Appendix 6.

3.3.3.5 Questionnaire

Access to a report of an evaluative study conducted by the University's Postcompulsory Education Centre using the same cohort of PBL students was requested and obtained (Gabb & Keating, 2006). This study used a questionnaire to gather data about age, previous school experience, socio-economic status, family education history, languages spoken, work status while undertaking the course, access to computer and internet from home and their main reasons for enrolling in this course. The findings of this study provided important demographic data regarding the participants of this study. The findings of this study, which is presented in Chapter 4, alerted the researcher to the heterogeneity of students enrolled in the course and to factors such as their previous school and work experiences that needed consideration when analysing their learning approaches in this PBL setting.

3.3.3.6 The group problem-solving activity

This simulated engineering situation was designed to gather information about students' application of generic skills and the disciplinary and cross-disciplinary knowledge that they had developed during the first year of their degree course through PBL. Particular attention was given to their use of communication skills, team-work skills, time management, information literacy skills, innovative thinking, disciplinary knowledge and cross-disciplinary knowledge when working on the problem.

This activity was conducted at the end of the first year course with the eight randomly selected student participants of this study. After negotiating a time that was convenient for all of the students, the selected students who were members of several different PBL teams were allocated into two teams depending upon their availability. Both teams were given the same problem. The problem-solving activity was designed so that it could be completed within the time span of a normal PBL supervised meeting. I played the role of a facilitator and operated on the video-recorder simultaneously. Data for this activity was collected by means of observation. The activity was audio and video-recorded to aid revisiting the data at any stage. Students were provided with a problem document detailing the problem-solving task and the expected outcomes. This problem document is presented in Appendix 7 and a summary of the problem statement and the expected outcomes are presented in Chapter 8.

3.3.4 Data Analysis

According to Bogden and Biklen (1998), qualitative data analysis involves systematically searching and arranging the data collected through various methods in a study. During analysis, data collected through various methods including interviews, observations, photographs and archival documents are amassed to firstly bring some sort of structure and meaning and then to uncover the important findings of the study undertaken. Qualitative studies aim to provide a specific result from a general concept.

According to Creswell (1998) during the process of analysis, information from observations and interviews should be brought together for transformation into a meaningful description or a summary form. He suggested that summarised data may be stored and organised in a personal computer and backed up in digital media for further analysis and descriptive writing.

Miles and Huberman (1994) suggested that the researcher may code the data and count codes to find how frequently similar codes appear in the database. Coding is the process of 'dissecting' the data and giving labels to units of meaning so that it is easy for the evaluator to pool ideas to cluster and later draw conclusions (Hurworth, 1996). It is noted that this exercise may lead to relating the categories and developing a theoretical framework, which may eventually lead to comparisons and contrast that can end up in redesign or generation of a new framework. Practical hints in the literature suggest the use of computer software applications, for example NVivo, to code data, categorise codes and identify themes (Bazeley, 2007). Inferences can be drawn from the coding of data to provide a structure for interpretation (Wolcott, 1994).

Bogdan and Biklen (1998) recommend jotting down notes in the margin of texts while doing a general review of the information collected, for example in observational field notes and interview transcripts. Creswell (1998) favours reading through all the information to obtain sense of the overall data in addition to writing findings in the form of memos and reflective notes during the initial sorting out process. All of these methodology scholars recommend commencing analysis early in project. It is noted that early analysis has the advantage that the field worker can think about initial data so that new questions or alternative collection techniques can be instigated to create even stronger data. Early analysis also permits the creation of interim reports that are often required in evaluation and policy study (Hurworth, 2008). For this research study there were three steps in data analysis. They are description, analysis and interpretation (Wolcott, 1994). But, as a first step, pseudonyms were used to protect the identity of student participants and to maintain confidentiality. Student teams were identified with numbers and the names of their supervisors were not recorded to ensure anonymity and confidentiality.

3.3.4.1 Description

The description phase was the initial phase of data analysis in this study. The strategies that were followed during this phase included transcribing audio and video data, summarising field notes and integrating it with the transcript of video-recorded observations, taking notes, making memos and sketching initial ideas. Data analysis in this study began with transcribing the audio and video data. The audio and video-recorded data were transcribed at the first available opportunity soon after they were collected. This process was ongoing as data were collected over two semesters for one year.

Initially, Microsoft Windows Media Player 10 was used for transcribing the audio recorded interview data recorded using a digital voice recorder. Thirty minutes of audio-recorded data required approximately four hours to transcribe. Examples of audio transcripts are presented in Appendix 8. However, the time required to transcribe reduced significantly when the Transana software application was used for transcription (D. Woods, 2006). Towards the end, 30 minutes of audio-recorded data only required approximately one hour and fifteen minutes to transcribe. Video-recordings were transcribed using Microsoft Windows Media Player 10. The video-recorded data included formal and informal observations, team oral progress presentations and the group problem-solving activity. An hour of video-taped data required approximately seven hours to transcribe. Forty hours of video-taped data were transcribed in this study.

Observation field notes were summarised and were integrated with the corresponding video data, thus ensuring the collected data were not lost or forgotten. During this process, observation summaries were drafted to identify key ideas that emerged from the observation data. These ideas enabled some initial coding of the data and most of these ideas are used in this study as codes. While these initial steps in analysis helped to gain an understanding of what happened in a particular meeting or what a student said about learning in PBL during an interview, it was difficult to move away and make deeper and more conceptually coherent sense of these initial ideas.

To overcome this difficulty, Miles and Huberman (1994) suggested using memos as a sense-making tool. According to Miles and Huberman (1994), memos help in tie together different pieces of data into a recognisable cluster, often to show that those data are instances of a general concept. Thus, as an early step in analysis memos were written to combine ideas that emerged from the interpretation of the audio transcript of interviews, observation field notes and video transcripts. The initial ideas that emerged from early analysis were sketched on paper using simple diagrams and tables.

3.3.4.2 Analysis

This phase of analysis was focussed on reducing the data and therefore data analysis in this phase was approached as a two-stage process. In the first stage data were reduced by means of coding and categorising. The second stage consisted of writing narratives of individuals and their teams. The narratives of twelve students are presented in Chapter 5 and the narratives of their teams are presented in Chapter 6.

3.3.4.2.1 Coding and categorising

According to Patton (1987) coding is a tedious and creative process, during which patterns are uncovered and themes are identified by carefully considering 'what is really significant and meaningful in data'. It is argued in the literature that computer aided analysis cuts out most of the drudgery, helps systematic organisation of material, allows flexibility of ideas and permits complex testing of ideas or hypotheses (Hurworth, 1996). However, Hurworth (1996) noted that "formatting material, learning programs and playing with data may be addictive and hooking" thus consuming time to the detriment of other analysis tasks (p. 64).

After careful consideration of the advantages and disadvantages of using computer-aided analysis, it was decided to use the NVivo software application for coding and clustering the interview and the observation data. The developers of the NVivo software application claimed that it provides researchers with a set of tools to manage data, manage ideas, query data, graphically model and report from the data. Gibbs (2002) argued that it can be used for analysing data collected using a wide range of methodological approaches, as the tools provided by the developers of NVivo are method free. As student portfolios were available only in hard copy, manual coding and clustering methods were used exclusively for these texts.

Both the bottom-up and the top-down coding approaches were used for coding data in this study (M. B. Miles & Huberman, 1994). Bottom-up coding involved, coding the data from scratch using the key ideas that emerged from the data. Top-down coding involved using ideas from the literature as well as the codes that were developed during the bottom-up coding process.

Initially, a few interview and observation data were manually coded using a bottom-up approach. The codes that evolved during the initial manual coding process were used to code the rest of the data top-down by using them in the NVivo software application. Additional ideas and codes emerged during the computer aided coding process. The codes were then clustered to identify emerging themes and were categorised based on the themes that they represent.

Some of the codes that evolved during bottom-up coding were used to code the portfolio using a top-down approach. A similar approach was used to code the video-taped observation of the group problem-solving activity. However, ideas that emerged during coding were added to the list of codes and were categorised appropriately. Apart from this, ideas from the literature were used for top-down coding of the observation and interview data while analysing the data for research questions 2 and 3 concerning student learning outcomes.

In Figure 3.1 below, the NVivo project file that was used for analysis of the data collected for this study is shown. On the left hand side of the picture (navigation view), the sources of data such as focus group interviews, individual interviews and observations are displayed. The highlighted item “Focus group interviews semester 1, 2006” is elaborated in the main section of the picture (list view), which indicates the total number of codes present in each focus group interview and the total number of references made to those codes. The date of creation and the date of modification also appear in the list view, which enables keeping track of any updates to the project file.

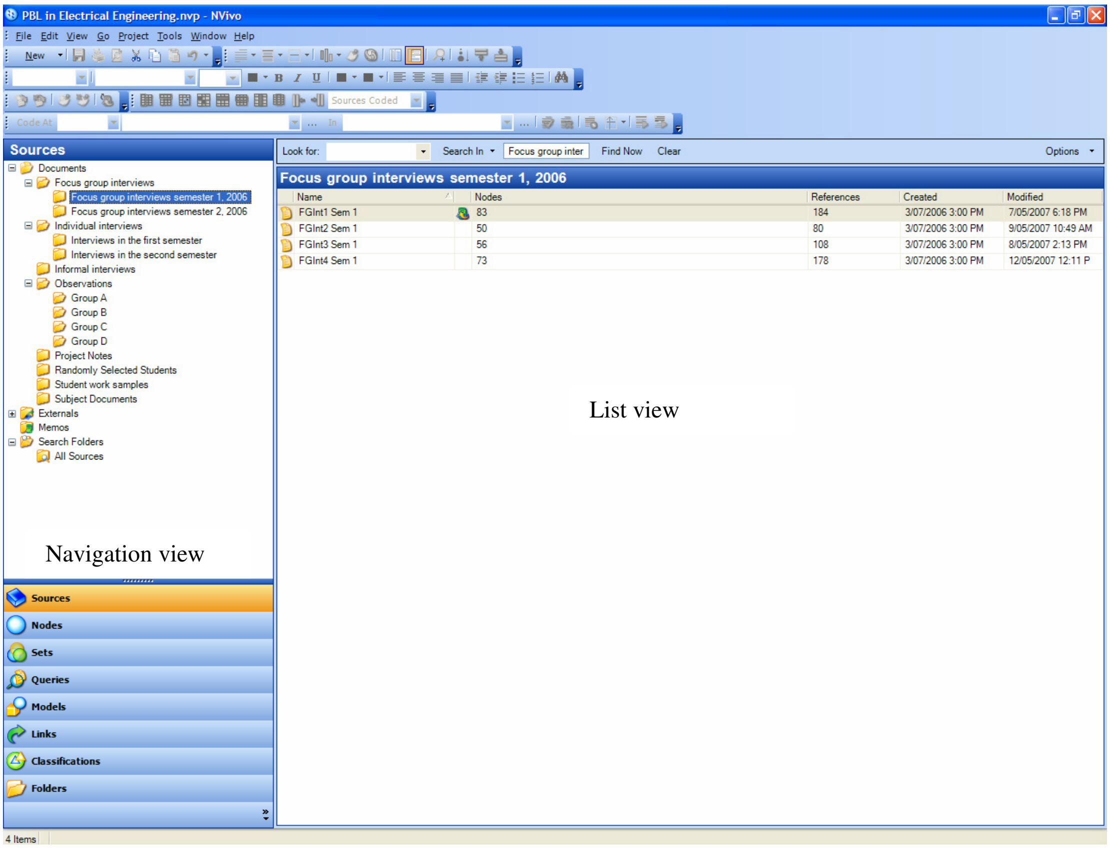

Figure 3.1 NVivo project window showing sources of data

Figure 3.2 below illustrates some sample codes that evolved during the coding process. The NVivo software application provides detailed information about the number of times a particular code was used for different sources and the total number of references to that code in all sources. In Figure 3.2, the codes that correspond to the categories of group and individual learning behaviours of students are presented. A rectangular box highlights the code 'freedom'. This code summarised data when students perceived that learning in a PBL setting gives them the freedom to choose what they wanted to learn. This code was used for three different sources and has been referenced four times in those three sources. At a later stage this code was moved from the category 'Individual learning behaviour' and placed in the category 'Attitudes' as it reflected more about their attitude towards learning in PBL than their learning behaviour.

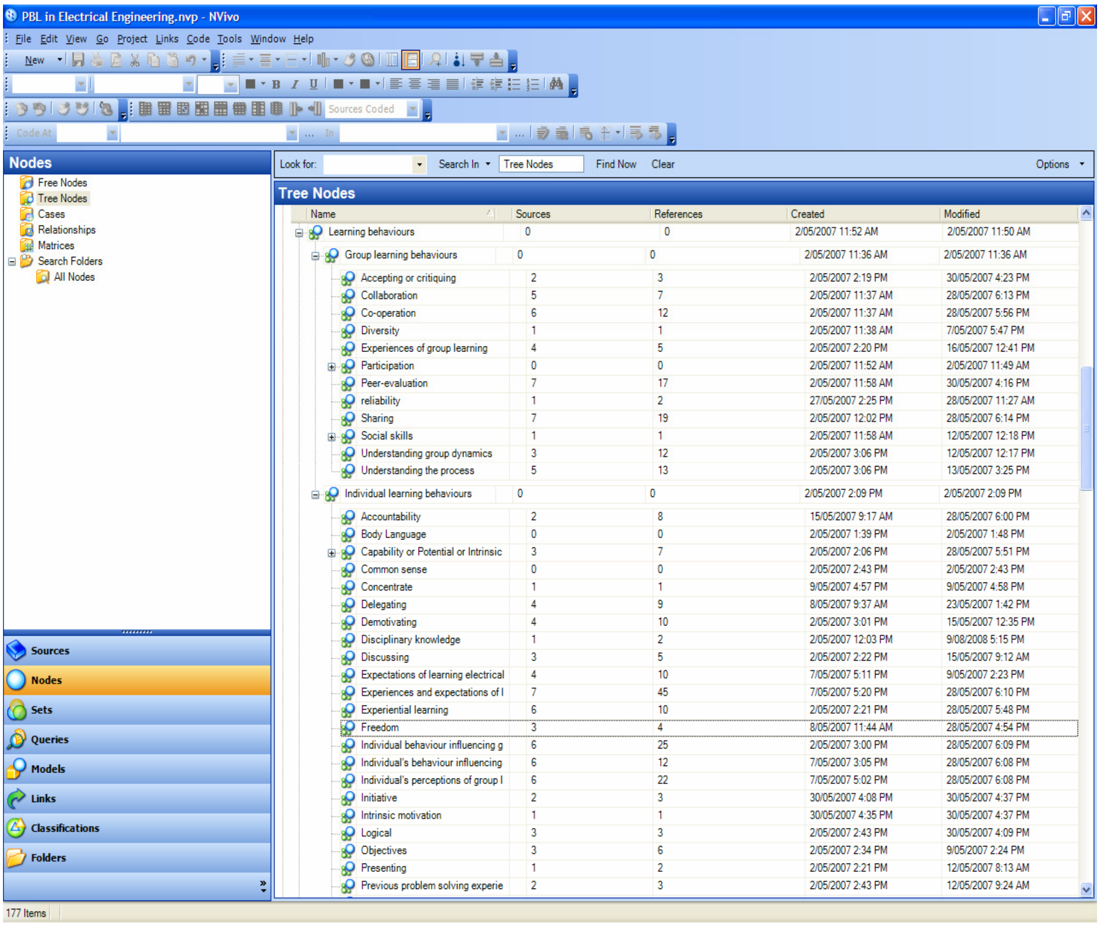

Figure 3.2 NVivo project window showing codes and categories

3.3.4.2.2 Narratives

The next stage in this phase of data analysis involved obtaining feedback on initial ideas and making metaphors. Miles and Huberman (1994) argued that in any study that has multiple cases, the meaning of what is happening in each case tends to get lost in the process of coding and therefore recommended using case analysis meetings. During this stage of analysis I met with my supervisors once every week for at least one hour to summarise the current status of each student and each team. These meetings generated a series of critical questions that required reflection. Notes taken during these meetings helped to focus and refine my thinking.

Combined descriptions (narratives) of the data were generated by drawing inferences from the patterns that emerged about individuals and their teams from coding and categorising observation summaries, interview transcripts and student portfolios. Thus the data were reduced to narratives, in other words rich and thick descriptions about twelve individuals and the eight teams of which they were members, while keeping the sub-questions of the first research question as the point of reference. The narratives of students and teams are presented in Chapter 5 and 6 respectively. Although the narratives gave an account of what had happened with respect to a student or a team, it was necessary to see the processes and learning that happened in this PBL setting at a deeper level to gain broader sense of the learning cultures in PBL teams. Therefore, it was necessary to move to the next level of analysis.

3.3.4.3 Interpretation

The last phase of data analysis involved systematic searching and manual top-down recoding of these individual cases to check and refine the codes and categories. Miles and Huberman (1994) argued that the important reason to conduct cross-case analysis is to deepen understanding and explanation. They suggested that the researcher can "calculate where a given order of events or incidents is most likely to occur or not occur" (p. 173). By systematically identifying similarities and differences across cases, cross-case analysis also helps the researcher to identify negative cases to strengthen a theory, enhance generalisability and identify the relevance or applicability of the findings of a study to other similar settings (M. B. Miles & Huberman, 1994).

Therefore, cross-case analysis was used to compare and analyse similar patterns that emerged from individuals as well as from teams. These patterns that emerged during the cross-case analysis were called attributes in this study and were analysed for different dimensions with particular reference to the research question of interest. Further, cross-case analysis was also used to identify patterns in the attributes and dimensions that corresponded with the relative success of the different PBL teams. These patterns were used in defining the learning cultures that emerged from eight PBL teams.

Miles and Huberman (1994) suggested that the secret of getting from data collection to the final report is by displaying data. It is suggested that a display, generated either by hand or by using a computer program, will help organise data in an efficient way and focus thinking (Denzin & Lincoln, 2003; Hurworth, 1996). During this phase of analysis, simple diagrams and matrices were used to organise data efficiently and to focus thinking. Tables 6.3 and 6.4 presented in Chapter 6 are examples of tables that were generated during this phase of analysis[1]. The key ideas that emerged during this phase of data analysis were used to structure the argument presented in the findings sections in this dissertation.

Interpretation became easier as all necessary information was assembled in tables, matrices and diagrams. For example, the analysis presented in Chapter 7 on what students learnt through PBL during their first year from the data collected through observations, interviews and student portfolio took approximately 20 days to organise in a matrix but only took about five days to interpret and write-up. A few examples of matrices and diagrams generated during the data analysis phase of this study are presented in Appendix 9.

3.4 Credibility and trustworthiness

Ethnographic research methods allow the flexibility of using the methods of investigation characteristic to one discipline to be imported and applied into another by using pre-designed conceptual frames and instruments, especially when dealing with multiple cases with a pragmatic approach (M. B. Miles & Huberman, 1994). However, it is essential to ensure the rationality and trustworthiness of the methods adopted by the researcher for the study, which supplement the credibility of findings and conclusions (M. B. Miles & Huberman, 1994).

As in any qualitative study, the validity of findings was a crucial component for this study. Miles and Huberman (1994) have argued that the quality of qualitative research underlies the goodness of the conclusions reached. They argued that noting patterns, making metaphors, clustering, subsuming particles into the general and factoring are crucial tactics for generating meaning. Further, they noted that checking for representativeness, checking for researcher effects, triangulating, weighting the evidence, using extreme cases, looking for negative evidence and getting feedback from informants are some tactics for testing and confirming findings.

In this study, I used some of these methods to simplify data management thus ensuring the credibility of the findings. For example, representativeness was checked by using a large sample size. Fifty students out of the 79 students who enrolled in the

[1] See Appendices 9, 10 and 11 for more examples of tables generated during data analysis.

first year electrical engineering degree were observed and informally interviewed. Ten students were randomly selected for observations during supervised team meetings and individual and focus group interviews. Apart from this, four students from the general cohort are described in this study because of their archetypal behaviour which became evident during analysis.

My role as a researcher was made clear to all participants to minimise the effects on their social and learning behaviours of the researcher's presence in the PBL studios and other learning spaces such as laboratories. To ensure accumulation of strong data, I collected all of the data in this study myself. Interviews were audio-recorded and some observations were video-recorded using digital recording methods and are stored in multiple computers and removable data recorders to ensure safe-keeping and revisiting of the data.

Throughout the study, I discussed my progress with my principal supervisor and associate supervisor to confirm and validate my interpretations and findings. Feedback from participants was also used to confirm the credibility of the findings. I contacted three students out of the twelve students reported in Chapter 5 during the writing-up stage to obtain their feedback regarding the data involving them as well as their teams. These students confirmed that my interpretation was well-founded. One student provided more data about himself to confirm my interpretation.

The findings of the group problem-solving activity were also used to triangulate the overall findings about what and how students learnt through PBL in their first year electrical engineering course.

Finally, I subjected the study to peer review throughout its development by publishing and presenting various aspects of the study at national and international conferences (Krishnan, Vale, & Gabb, 2006, 2007a, 2007b, 2008).

3.5 Summary

To summarise, the research questions and research processes used to investigate the life of first year electrical engineering students in a newly implemented engineering problem-based learning (PBL) curriculum, its effects on their approaches to learning and their learning outcomes have been presented in this chapter.

The qualitative methodology presented in this chapter was designed to capture and theorise learning in a PBL setting from the students' perspectives. Their attitudes, behaviours and approaches to learning as a team and some specific learning outcomes that are believed to be promoted in a PBL setting were explored by analysing the ways in which these students approach and direct their learning as individuals and in teams.

Ethnographic observations, interviews and a group problem-solving activity were conducted to collect data for this study. Samples of student work and course documents were also collected. In the following chapter, information about the location in which this study was conducted and the findings of the PBL survey study conducted by Gabb and Keating (2006) which provided important information about the participants in this study will be presented.

Chapter 4

Description of PBL program and students

4.1 Introduction

The intention of this chapter is to provide details about the setting in which this study was conducted and the participants in this study. Accordingly, this chapter is divided into two sections. In the first section, the PBL program is briefly described based on the course documents that were collected during the study. The second section consists of a description of the participants of this study, drawing on the results of a series of student surveys conducted by staff of the University's Postcompulsory Education Centre during the same period as the study reported here (Gabb & Keating, 2006).

4.2 The PBL program

4.2.1 Location

This study was conducted at Victoria University, an institution with 11 campuses located in the western Melbourne region and in the Melbourne central business district. It has over 45,000 students, including off-shore students, and approximately 3500 staff members. The University is a dual sector institution and offers a range of courses from non-award courses to postgraduate degree courses. It has three faculties in higher education, two in vocational education and VU College, which has a further education focus (Victoria University, 2007a). A majority of students studying at Victoria University reside in the western region of Melbourne.

4.2.2 Undergraduate Degree courses in Engineering

The Faculty of Health, Engineering and Science offers scientific and professional courses that are recognised by various professional accreditation bodies such as Engineers Australia, the Australian Computer Society and the Nurses Board. The admission requirements for such courses are similar to those of other Australian universities. A bridging program is available for students who are unable to meet the usual admission requirements (Victoria University, 2006).

At the time of the study, undergraduate degree courses were offered by the School of Electrical Engineering and the School of Architecture, Civil and Mechanical Engineering in the following areas:

- Electrical and Electronic Engineering;
- Robotic Engineering;
- Architecture Engineering;
- Building Engineering;
- Civil Engineering;
- Mechanical Engineering (Victoria University, 2005).

The undergraduate engineering courses allow students to specialise in a wide range of disciplinary areas. For example, the Bachelor of Electrical and Electronic Engineering course allows students to specialise in areas such as computer engineering, software engineering, microelectronic systems, telecommunications engineering, power systems engineering, control systems engineering, photonics, robotics and automation. The course provides foundation subjects in the first two years and allows students to choose their area of specialisation in years three and four (Victoria University, 2006).

4.2.3 Problem Based Learning at Victoria University

Problem based learning (PBL) was introduced to the School of Electrical Engineering and to the School of Architecture, Civil and Mechanical Engineering in 2005. Each school designed their own PBL curriculum and implemented it in the courses offered by the school. The main aim of introducing PBL at Victoria University was to produce “industry ready” engineers (Victoria University, 2007b).

This study focused on the implementation of PBL in the School of Electrical Engineering. From Semester 1, 2006, PBL was progressively introduced (Ives, 2005) into the undergraduate degree courses in the School of Electrical Engineering. The Bachelor of Engineering in Electrical and Electronic Engineering (4 year undergraduate course) and the Bachelor of Engineering Science in Electrical and Electronic Engineering (3 year undergraduate course) were the two courses that adopted the newly designed PBL curriculum from the beginning of the academic year 2006. Students who applied to study either of these courses were required to have studied grade 12 mathematics or equivalent. The Bachelor of Engineering in Robotic Engineering also adopted the newly designed PBL curriculum from the beginning of the academic year 2006. However, Specialist Mathematics or Mathematical Methods in grade 12 and a study score of at least 22 were prerequisites for gaining an entry to this course (Victoria University, 2006).

Each semester is of 12 weeks duration at Victoria University. Students who study full-time were required to enrol for subjects totalling 48 credit points in total each semester of any given academic year. From the beginning of the academic year in 2006, in the courses that adopted the PBL curriculum, the total of 48 credit points in each semester was divided between two non-PBL subjects with 12 credit points each and one PBL subject with 24 credit points (Victoria University, 2006). The details of these subjects in the first year course are discussed in the following section. At the time this study commenced, it was unclear how PBL would be included in the following years of the course (Ives, 2005).

Students who failed to obtain a pass in a PBL subject would be required to repeat that subject in the following semester, as the PBL subjects were treated as core subjects (Victoria University, 2006). Students also had the option of repeating a PBL subject during the shortened summer semester, provided that subject was offered in that semester. The course structure of the first year electrical and electronic engineering undergraduate degree program is shown in the following Figure 4.1.

In this implementation of PBL, a “team” was defined as a set of students who worked together as a team in PBL and a “group” was defined as a larger set of student teams who were facilitated by the same supervisor. Students who enrolled in PBL Subjects 1 and 2 were assigned to one of one of four groups with approximately five members. Students either self-selected their team or were allocated into a team by their supervisor. Each team met with their supervisor for approximately one hour each week during the semester.

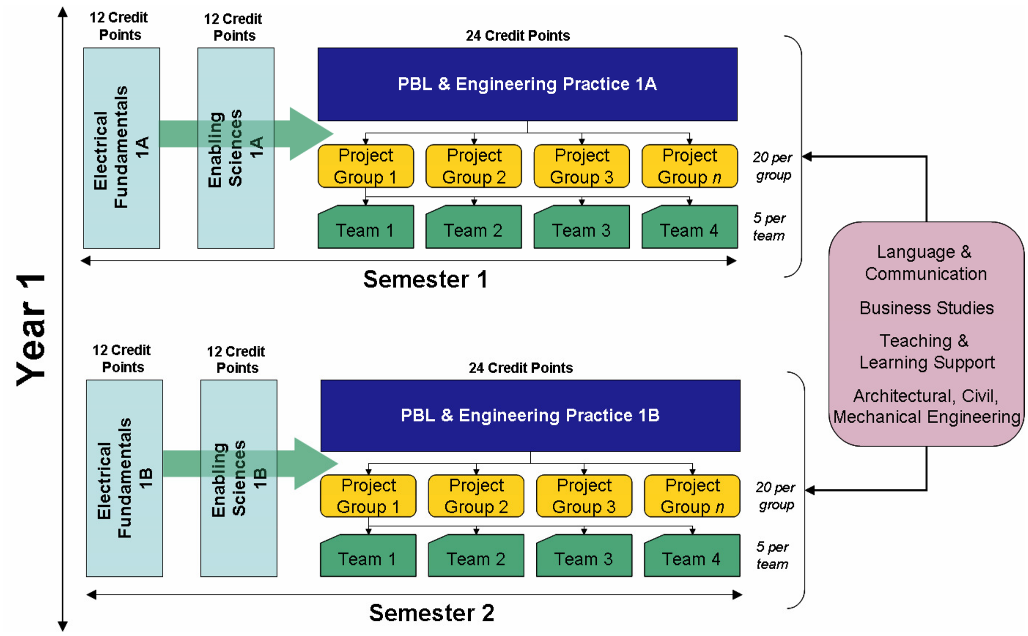

Figure 4.1 First year course structure. Figure source (Stojcevski, 2006).

4.2.4 PBL Curriculum

4.2.4.1 Course Objective

The Bachelor of Engineering and the Bachelor of Engineering Science courses in electrical and electronic engineering already provided a foundation for electrical disciplinary studies and specialisation in the areas of communication, computer, control electronic and power engineering. The introduction of PBL was intended to scaffold the development of personal initiative and enquiry in students that might be applied in their continuing professional development as they met the technological changes in their profession. Students were expected to form an awareness of holistic nature of engineering as they approached problems and to form an understanding of the role of an engineer in the society as they solved them. The course also met the requirements for professional recognition by the Engineers Australia and other professional bodies (School of Electrical Engineering, 2006).

4.2.4.2 PBL Subject details

In both first and second semester, the course consisted of a single PBL subject (24 credit points or 50% of each semester's load) and two other non-PBL subjects concerning physics, circuit theory, computer programming and mathematics. Students were expected to commit 120 hours each semester to the PBL subject. Every week there was a scheduled one-hour PBL team meeting, in which student learning was facilitated by PBL supervisors. At other times, students were expected to work unsupervised both individually and in their teams. Technical staff members were available to assist students with laboratory work. Language and communication facilitators were available on a weekly basis to assist with the development of language and communication skills. Specialist engineering lecturers delivered additional support lectures and workshops to support student learning in the PBL subjects.

4.2.4.3 PBL Subject 1 – Semester 1

In this subject students worked in teams to solve three problems designed for this subject (See Appendix 5). The first problem, which was designed to establish teams and develop team work skills, required students to construct a mobile robot. The second problem required students to design and construct a single channel audio power amplifier using a well known LM386 integrated circuit audio amplifier with particular specifications. The third problem required students to investigate the suitability of photovoltaic array systems as primary sources of energy in a sustainable environment. For this problem, they were also asked to address the ability of such systems to recoup the embedded energy, pollution both in manufacturing and end-of life of the components, cost of purchase and operation costs, and reliability of the energy supply. Students were expected to learn measurement and testing techniques as part of the testing and reporting process. They were required to design, perform experiments and produce a referenced research report for both the second and the third problem. Students were also required to make a presentation on their solutions using audio-visual aids, to submit a team technical report and to submit individual reflective reports for the second and third problem.

4.2.4.4 PBL Subject 2 – Semester 2

Unlike the PBL Subject in Semester 1, this subject was based on a single project (see Appendix 5). Students were able to negotiate changes to the membership of their Semester 1 teams. Some chose to remain in the same team but a majority moved to another team. Most students were given the problem description (Traffic Automation) in the first week. They were asked to identify a traffic intersection in Melbourne that had traffic-light timing problems. In particular, the students were asked to identify an intersection that connected a main road that was frequently used by people commuting to work and a side street that was mostly used by local residents. The problem description gave no guidance on the methods or concepts that students might use in addressing the problem. Students were given nine weeks to provide a solution to the problem in the form of a proof of concept. They were required to implement the traffic automation concept and report back. The problem description did not provide information on assessment tasks or expected outcomes. Supervisors verbally informed students that they were required to present the group's progress in Week 5 and a final group presentation in Week 12, both using audio-visual aids.

4.2.4.5 Assessment

Students were summatively assessed in both subjects only on the basis of an individual portfolio submitted in the final week of the semester. There was no formal examination. For the purposes of grading, the PBL supervisors used Biggs and Collis's (1982) Structure of the Observed Learning Outcome (SOLO) taxonomy to assess the level of achievement of each learning outcome for that unit. The expected learning outcomes for PBL Subject 1 are shown in Figure 4.2.

Apart from the portfolio, students were also required to submit a mid-semester team progress report consisting of a technical report and a personal reflective report soon after their progress presentation during Week 5 or 6 during the semester. These reports were only used for formative assessment.

In the portfolio, students were required to demonstrate the attainment of all the subject learning outcomes, including their ability to effectively work as a team. The portfolio was expected to contain peer evaluation and self-evaluation data and other evidence of participation and contribution to weekly team meetings, audio-visual project presentations as well as other written work such as: reflective essays, expositions, and technical reports. They were also asked to submit log books used by the team (including attendance and minutes of meetings). The learning outcomes were similar for both of the first year subjects.

- Demonstrate the successful completion of a project(s) in a specified time period.
- Demonstrate professional engineering skills.
- Use a computer to perform word processing as a communication tool.
- Use a computer to create spreadsheets and graphical outputs for reports.
- Demonstrate an awareness of general electrical safety standards.
- Demonstrate an understanding of the social and technical roles of a professional engineer.
- Demonstrate an awareness of the uncertain nature of some engineering designs.
- Communicate to professionals and non-professionals the fundamentals of the "language of engineering".
- Locate, evaluate, manage and utilise critically information for a range of purposes.
- Utilise basic electronic devices and incorporate them into a working design.
- Operate a range of standard electrical engineering laboratory equipment.
- Demonstrate an ability to write software programs.
- Demonstrate an ability to work as part of a team.
- Demonstrate abilities in time management.
- Demonstrate an ability to undertake lifelong learning and the capacity to do so.

Figure 4.2 Learning outcomes from unit of study guide for PBL Subject 1.

These learning outcomes were elaborated and presented in a matrix showing the relationship between these learning outcomes and the eleven core graduate attributes required in all undergraduate courses offered by Victoria University (Stojcevski, 2006). A sample of this matrix can be found in the problem brief attached in Appendix 5. Other than the information provided about assessment in the unit of study outline, specific instructions about expected tasks were also found in the problem documents in Semester 1. However, no instructions or expected outcomes were attached to the project document that was given to students in Semester 2.

4.2.5 Learning spaces

Students were provided with PBL learning spaces (studios). These learning spaces were specifically provided for the first year PBL student to meet and learn as a team in PBL. During Semester 1, students shared six temporary suites as shown in Figure 4.3. All six studios were located inside the same room and were separated by removable carpet room dividers as shown in Figure 4.4. Student teams were rostered to access these studios during the week. Access was not provided during the weekend. Students were also provided with a lock-up cupboard in the PBL area to securely store their personal belongings such as books, testing and measuring equipment.

Figure 4.3 Semester 1, 2006; PBL studio

Figure 4.4 Semester 1, 2006; PBL room

During Week 4 in Semester 2, each student team was provided with its own PBL studio as shown in Figure 4.5 below. However, as access (using an electronic key) to these new studios was made available to students in a phased manner, many students either accessed the study area with the help of their supervisors or with the help of other students who were already in the studios before them. Some students complained that this situation limited their opportunity for face-to-face unsupervised meetings. It was Week 8 in Semester 2 before some teams were provided access to these studios. The new studios were fitted with wireless internet access. Apart from this, three computers and a laser projector facility were provided in a common room called the PBL Common Area, where students made presentations of their progress. The PBL Common Area is shown in Figures 4.6 and 4.7 below.

Figure 4.5 Semester 2, 2006; PBL suite/studio

Figure 4.6 Semester 2, 2006; Computers in PBL Common Area

Figure 4.7 Semester 2, 2006; Audio / Visual aids in PBL Common Area

4.3 Description of participants

As reported in Chapter 3, 50 of the 79 students who were initially enrolled in the course agreed to participate in this study. Eight supervisors also agreed to participate in this study during observation of students. Five supervisors were electrical engineering teachers and three were from the School of Communication and facilitated language and communication skills during supervised PBL team meetings.

During informal interviews with participants, it was found that two students who were enrolled in PBL Subject 1 and 2 were in the second year of the undergraduate robotic engineering degree course. The youngest student participant was 18 years old and the oldest was 36 years old. Of the 79 students, only four were female. All four female students participated in this study.

Gabb and Keating (2006) conducted a series of surveys which explored the experiences of students as they adjusted to this PBL setting. As the study reported on the characteristics of students who enrolled in the PBL subjects offered by the School of Electrical Engineering, its findings were obtained from the researchers and were used in the current study. The study reported that a majority of the students enrolled in the PBL subjects offered by the School of Electrical Engineering were aged 18-24 years. Less than 10% of the students were aged 25-30 years and only two students were above 30 years of age. Except for one student, all were enrolled as full-time students.

The study reported that 90% of the students had finished high school between 2002 and 2005. More than half of the students studied at a Government school in final year of school. Nearly fifteen percent of students had attended an independent or private schools and just over 20% of students had attended Catholic schools. Nearly 10% of students reported that they studied in a school overseas in their final year of school.

The evaluative study also reported that 50% of students spoke a language other than English (LOTE) at home. An equal percentage of students were categorised as low SES according to the postcode of their home residences. One third of the students' homes were in the western metropolitan region. From the findings of this study, it was evident that the course had a high proportion of students of low socio-economic status (SES) and with a language background other than English.

Gabb and Keating (2006) determined the socio-economic status of students using the Australian Bureau of Statistics (ABS) Socio-economic Indexes for Areas (2001) software package to compare students' home postcodes with those of Victoria as a whole. Their findings indicated that for the PBL student cohort the average value on the Index of Socio-Economic Disadvantage was below the Victorian average. This index is most commonly used to focus on low-income earners, relatively low educational attainment, high unemployment, rental dwelling and lack of English fluency. Gabb and Keating (2006) argued that a low index value is a sign of disadvantage, but a high value reflects lack of disadvantage rather than high advantage.

Only three students had dependents and a little less than half of the students were the first in the family to attend university. They reported that a quarter of the students had previous engineering experience and that seven students had engineering work experience. Eleven students had studied engineering previously and four students had other engineering experiences.

Nearly 70% of the students were involved in some form of paid work and 20% indicated that they had not undertaken any paid work previously. They found that most students who were involved in paid/unpaid work, worked between 10 and 20 hours per week. They also found that students who worked in paid/unpaid jobs were slightly more likely to have come from high SES backgrounds and language backgrounds other than English.

The overwhelming majority of the students indicated that they would either definitely or probably be able to support themselves financially during their degree course. They also found that most students had a home computer and internet access with 65% of students indicating access to broadband internet at home. However, they also found that five students had no access to internet facilities at home and two students did not have access to a home computer.

Half of the students travelled between one and two hours to reach the campus. It was also reported that two students travelled more than two hours and the rest of the students travelled either less than 30 minutes or between 30 min and one hour to reach the university campus.

Gabb and Keating (2006) found that a majority of the students chose to enrol in this course for reasons based on both intrinsic motivation ("studying in a field that really interests me" and "developing my talents and creative abilities") and improving their prospects for getting a job (p. 13). They reported that intrinsic motivation was more highly rated by students than other reasons for joining the course. However, they found that more than half of students from a language background other than English rated meeting "expectation of my parents or family" as important (Gabb & Keating, 2006).

4.4 Summary

To summarise, the setting in which this research study was conducted and the characteristics of the participants were explored in this chapter. Key information about the design and implementation of a new PBL curriculum at the School of Electrical Engineering where this study was conducted were presented. It was found that in both first and second semester the course consisted of one PBL unit and two lecture-based non-PBL units. Information about the objectives of the course, and the course structure suggested that the School planned to teach fundamental electrical engineering knowledge for solving problems in the PBL subjects through the non-PBL units additional to the workshops and support lectures for the PBL subjects. This indicated that PBL in this setting was used as an instructional strategy in conjunction with lecture-based subjects (Conway & Little, 2000).

Particular information about the PBL subjects suggested that PBL subject 1 was problem-based whereas the PBL subject 2 was project-based. Both formative and summative assessment methods were used in the PBL subjects. However, it was found the main method of assessment was summative and student learning was assessed in both PBL units by means of a portfolio that students were required to submit at the end of each semester. Information about the resources that were provided to students, including learning spaces, access to computer, internet and laboratory facilities, were also identified and presented in this chapter.

The findings of the evaluative study conducted by Gabb and Keating (2006) revealed demographic information about the student participants in the study such as their language background, socio-economic status, previous school and work experience and their type of enrolment in the course (full-time or part-time). The majority of students enrolled in the PBL subjects were aged between 18 and 24. However, the study also found that some students were mature aged and had previous engineering work experience. This study also found that nearly 70% of the students were involved in ten to twenty hours of paid work during their full-time enrolment in the course. These findings alerted the researcher to the heterogeneity of the students who enrolled in the course and guided the analysis by refining the focus about the diverse nature of students and interpreting the ways in which they participated in learning in this PBL setting.

As has been noted before, PBL was implemented as the main method of teaching and learning in the School of Electrical Engineering for the first time in the year of this study. The experiences of these first year engineering students in this newly implemented curriculum; its effects on their approaches to learning and some of their learning outcomes are presented in the following chapters.

Chapter 5

The student: Learning approaches

5.1 Introduction

As described in Chapter 3, the main aim of this study is to investigate the student experience of a problem-based learning curriculum and to report on the learning culture that developed in this PBL setting. The aims of this chapter are to identify the ways in which individual students approached their learning in a PBL setting and the ways in which their attitudes and behaviour influenced their approaches to learning. This chapter focuses on individual students, while the next chapter focuses on PBL groups and the learning cultures that developed in each group.

Previous research has indicated that the learning approaches taken by students influence their learning outcomes. In Chapter 2, it was noted that Biggs and Moore (1993) identified three approaches to learning each with a corresponding motive and strategy. This theory provides a basis for analysing student learning approaches in any setting. However, when applying Biggs's classification of student learning approaches in a team setting such as PBL, it is important to consider the roles that individual students take in their team, their tendencies to participate in a team environment and their engagement in learning activities as a team.

Different facilitation methods, curriculum settings and course characteristics will produce a variety of learning environments and thereby influence the learning approaches students adopt. In a group-based PBL setting the attitudes and behaviours of the individual students in each team will influence the learning approaches in that team as well as contribute to their learning cultures.

As discussed in Chapter 2, the term "learning culture" is used predominantly when describing learning that happens at a work place. In this study, the shared beliefs and theories of students in each PBL team and their approaches to learning in PBL as a team define the learning culture for that team.

The shared beliefs of each team will be in part determined by the attitudes and behaviours of individual students along with their individual approaches to learning in a PBL setting. As students from diverse social and educational backgrounds participate in learning, it is expected that the group learning culture will reflect this diversity as well.

It is also anticipated that the learning culture in a PBL team will be influenced firstly by the attitudes and behaviours of individuals who are members of that team; secondly by the beliefs, norms and values of the individual members and the developing group beliefs, norms and values; and finally by individual perceptions of the situation that is the curriculum, the problem and the assessment system in the PBL setting.

Hence, the first research question, "What are the learning cultures in a problem-based learning environment?" focuses on the team learning cultures that develop and the ways individuals influence these team learning cultures. In this chapter particular emphasis is given to the sub-questions of the first research question.

- How do students from diverse educational, linguistic, ethnic and religious backgrounds participate in the context?
- How do the students approach learning?
- How do the students control, regulate and direct their learning?

These questions will be explored and discussed by analysis of students' reflections on the PBL environment (which were gathered by various methods e.g. interviews) and their attitudes and beliefs (interpreted on the basis of their observed behaviours, actions and approaches while learning in the PBL environment). It is expected that the analysis of individuals' attitudes, behaviours, actions and learning approaches in a PBL team will provide an insight into the beliefs and norms of that PBL team and the team's learning approach. This analysis will thereby inform the learning culture of each team and the learning culture in problem-based learning more generally within that class. The theme "learning cultures in problem-based learning" will be explored in depth in Chapter 6.

The findings presented in this chapter were collected over two semesters and were drawn from the field notes taken during observations, the transcripts of the audio-taped interview data, the transcripts of video-recorded observation data and the content of student portfolios. As explained in Chapter 3, the data presented in this chapter was analysed in three stages: description, analysis and interpretation. In the first phase, data from audio-taped interviews and video-taped transcripts were transcribed. Followed by this, data from the observation transcripts were merged with the transcripts of video-taped observation. In the second phase, data were then coded initially manually and then using the NVivo software application. Codes were then clustered to identify categories and sub-categories called attributes and dimensions in this dissertation. Inferences were drawn from the analysis during this phase and the data was reconstructed as cases based on individual students. The final phase involved systematic searching and manual recoding of the data presented in this chapter. During this phase, inferences were drawn about student approaches to learning in this PBL setting.

Accordingly, this chapter is divided into two sections. In the first section, cases of twelve students are presented to illustrate detailed accounts of their educational background, their expectations of studying the electrical engineering course, their perceptions of the PBL setting, the tasks that they preferred, the activities that they engaged in and the roles that they assumed. The social and learning interactions, attitudes, corresponding behaviours and the learning approaches of these twelve students are also explored and presented in their cases. Student characteristics such as peer support, commitment, initiative, planning inferred from their behaviours and their approaches when performing certain actions that help or hinder their learning in a PBL setting are also discussed here. The student cases are organised according to the learning approaches that they adopted.

In the second section, the data presented in this chapter are analysed. The attitudes and behaviours of these twelve students that influenced their approaches to learning in this PBL setting are explored here. The chapter concludes with a synthesis of findings to form a description of individuals' behaviours in PBL teams and their learning approaches. Links are made to identify how these individuals' motives influenced their roles in their teams and thereby their approaches to learning. Different individual learning approaches are compared to explore which roles lead to successful group learning. The attributes that are used to describe the individuals and their learning approaches will be further elaborated in the Discussion chapter.

5.2 Student cases

The data concerning twelve students are presented in this section. Of the 50 students who agreed to participate in this study, eight students were randomly selected for formal interviews and formal observations. Four additional students are included because of their archetypal behaviour. These students were chosen to illustrate different attitudes, behaviours and learning approaches that were identified in this study.

In this chapter, particular emphasis is given to the data collected from these twelve students named here as Edward, Ali, Jacob, Khadir, Theo, Lucas, Phillip, Timothy, Claire, Matt, Jeff and Bruce. This section contains detailed account of these twelve students. The attitudes and behaviours that influenced their approaches to learning are explored here. The account also contains details of the activities that they engaged in, the tasks that they preferred and the different team roles that they assumed.

The characteristics of three students are presented in the following summary Table 5.1 below, to illustrate the method of analysis. A summary table of the characteristics of all twelve students is presented in Appendix 10. It is recalled here that a PBL team consisted of approximately five students, who met with their supervisor for approximately one hour each week during the semester.

As described in Chapter 4, most students were part of the first year electrical engineering degree course that was offered in problem-based mode for the first time at Victoria University. Some students were studying second year of an undergraduate robotic engineering degree. However, it was the first time all of these students had studied in PBL mode in a tertiary setting.

Table 5.1 Summary table of PBL student characteristics

Students	Background	Main reason for joining the course	Focus	Understanding of PBL	Activities Engaged	Examples of resources used	Tasks preferred	Roles	Learning approaches
Jacob	Mature age student, introvert, has other family priorities	Family pressure, social reasons	Obtaining a highly paid job	Data was not collected	Completing individual tasks, writing his part in the technical report	Internet, computer laboratory	Computer programming	Did not take any consistent role. Mainly a freeloader	Surface approach throughout the first year
Claire	Mature age student, extrovert, enjoys socialising.	Enthusiasm to learn new knowledge, doing things hands on	Learning and excel in the field of engineering, enhancing career prospects	Learning as a group with a diverse set of students with varied experience and skills	Chairing meeting, delegating tasks, planning, organising team work and leading the team	Used prior knowledge in most of the tasks that she engaged, Internet, books from the state library	Writing, collating team members' solutions to individual tasks, experimenting.	Organiser, mentor and team manager, completer, admirer	Started off using deep approaches but focused on achieving a product in both semesters
Jeff	School-leaver, keen on gaining new knowledge	Job motivation, Employability	High paid job, high academic achievement, become an expert.	Team work and collaboration. Self directed, independent learning environment where technical skills are learnt in conjunction with generic skills.	Brainstorming, discussing and sharing ideas, organising tasks, sharing knowledge and leading the team	Internet, books, manuals from the University library, lecture notes, teacher and laboratory	Researching information, discussing with team members and actively contributing to the team's work.	Leader, contributor, innovator mentor and shaper.	Consistently used deep approaches throughout both semesters

5.2.1 Student 1, Edward

Edward was an Anglo-Australian student who entered university soon after secondary school. He entered tertiary education due to pressure from family members and thought going to university after secondary education was a social norm in his community. He enjoyed coming to university as he felt that university was an independent and fun environment and planned to make many friends. Edward also aspired to meet his ideal life partner at university. Apart from waking up at 7 a.m. and travelling to university in packed trains from the other side of the city, he seemed excited about his experience.

In Semester 1, Edward was just another team member in his team. He loved having fun in team meetings and was the clown of the team. He normally waited until his team leader or another team member asked him to contribute to the team. When he was assigned a task, he stated that he "gave it the best shot" he could.

Edward expressed concern about the attendance and accountability of two other team members. He suggested that if he was to take on such a passive role himself, then the team's progress would definitely suffer. He promised his team leader that he would help him in every possible way to see all the problems completed. Edward also indicated that he intended to replace one of the team members (Alex) in Semester 2:

> Alex turns up and comes to classes but, after the class he goes straight home. He pretty much walks straight to his car and drives home, say like you have to chase him to get him to do something and it's not worth it. Instead, may be we can send him an email of the last date when something is due.
>
> Once we had to do his tech report, we had to append his part and all that sort of thing. We are going to find someone who can put as much work as we put in.

While solving Problem 2, Edward's ideas were seldom considered by the team. While Edward did not express any concern about his ideas being neglected, he appeared to gain the impression that he could not think efficiently. He mentioned a couple of times during team meetings that his ideas were not effective. However, that did not stop him from contributing to the team. He helped his team leader to execute the leader's ideas in solving the problems. During an interview Edward mentioned that:

> I never really had much to put in. I am a dumb ass [laughs]. It was fairly straight forward with the problems most of it. Like, we were told what we had to do so, you went and did it

> and then you came back and occasionally we had to find out something. We were told what to research on and sometimes like, if I had an idea and I pitched it was stupid, mostly I would say: ‘They don’t really agree with that’.

In the third problem, Edward did whatever his team leader asked him to do. He soldered components on to the bread-board, tested circuits that were built by his team leader and also contributed to writing the technical report. He appeared to learn techniques from his team leader and constantly worked to improve his skills. At the end of Semester 1, he mentioned in an informal interview that he was unable to concentrate much on the other lecture-based subjects as the PBL subject consumed most of his working time.

> It wasn’t as hard as I initially assumed it to be. It required a little bit of work but, it went good. But it is still hard to keep PBL and your normal classes and not really concentrate on them like, sometimes you concentrate on PBL and you have to do some maths, there is always work sheets that you haven’t done and you just concentrate on, some other time to do that because you have to do PBL, so trying to keep both running at the same time.

At the beginning of Semester 2, Edward mentioned that he had failed both the lecture-based subjects but had managed to obtain a credit in the subject taught in problem-based mode. He appeared to be disappointed by his experience in Semester 1 and expressed an aversion to PBL. Edward openly expressed his feelings to his team members as well as to the members of other teams, saying:

> I never want to hear the words PBL. PBL is bullshit I hate it. Yeah, this semester is a joke. Last semester was actually reasonably good. We actually learnt stuff. But this semester is like inadequate... If you look at it this way, if you had failed the lecture-based subjects, which is programming and digital and circuit theory in Semester 1, you went up to this in Semester 2 and you had a group full of people that failed in Semester 1; you wouldn't be able to do this problem at all. Hey, can we get a refund for our course?

Edward’s “cool dude” behaviour attracted a few students to his team. During Week 3 of Semester 2, some new students joined Edward’s team. Edward spent time with these new members and started to expand his social circle. He made new friends with members of other teams and socialised with them at the university bar.

In Semester 2, Edward slowly started to experiment with the role of a freeloader. After Week 2, he started missing a few meetings. He rarely brainstormed during team meetings and almost completely stopped contributing to team discussions. Most of the time during supervised meetings, he remained silent. During unsupervised meetings, he demonstrated interest in socialising. He organised for unsupervised team meetings at the university's bar, which ended up in social activities. He frequently missed team meetings and complained that he could not get a grasp of the problem or of the ideas of his team members.

> [In Semester 1], they broke it up and they had every meaning less. OK this week you need to do this. It was more understandable. But this time it's like, OK where are you guys going now? It's like, it is hard to, you know the depth of this problem up here is one way down here and it's hard to understand what to do if you don't know what you are doing...

In Semester 2, Edward agreed that he only worked on tasks that were within his ability and he showed no interest in gaining new knowledge. Edward complained about a range of things such as access to the learning spaces, the problem, the teaching methods and also about his achievement in the previous semester.

> I think I have gone backwards. But, I don't think I have because this semester I have shut up and sat in the corner when I get f****g ah, because it's just, instead of cheering me up, worn me out. I don't care. Last semester was good, this semester they have just chucked this massive thing on us and go do it. It's like what are we doing? We didn't even get like a problem outline, they gave us one sheet once and then …

During a focus group interview, he expressed concerns about the teaching methods of a staff member, which he perceived as causing his failure in that subject. During the mid-semester break, he started a conversation on the University's learning management system (WebCT) and questioned the teaching expertise of this staff member. This conversation stimulated a long debate among students that included comments of a racist and sexist nature. Edward's action also sparked a controversy amongst PBL supervisors, who engaged in further discussions with other staff members to what kind of material should be allowed to be posted on such teaching and learning websites.

> [What is your contribution to your team's learning?]
>
> This semester or what? Man it's going to be difficult. This semester not very much. Because I don't really understand the problem that very well. [I only do] whatever is given to me or whatever I can do. Because I don't have a good understanding of the programming I think. Because I failed last semester because [Teacher] is f****n useless. And I can't understand him or what he is trying to teach. I have more gone to the problem and looked at the parts that I can do like statistics, going up to the intersection and providing other information that I can give rather than stuff that I have got no idea on. That's about all.

In his portfolio, Edward claimed that he had attended every meeting and completed all the tasks that were required of him. He indicated to the researcher that his contribution was only limited and that failing the lecture-based subjects in the previous semester had limited his knowledge and skills required to solve the problem in Semester 2. He nominated himself for a pass in the PBL subject in Semester 2 and reported that he had learnt some of the skills such as programming and digital electronics and claimed to have realised how important such skills were in the field of electrical engineering.

To summarise, in Semester 1 Edward played a supporting role in his team and offered help to his team leader whenever he was directed. He was neither intrinsically nor extrinsically motivated and did not bother to validate or apply new knowledge. In fact, he used a surface approach to learning and often complained that he did not understand the problem clearly. Moreover, he made minimal or no attempt to identify his own learning needs and was always directed by another team member or the supervisor to complete the tasks that were delegated to him.

Edward enjoyed socialising and made new friends outside his team, which contributed to his new role as a freeloader in Semester 2. He decided that he did not have the knowledge level to solve the Semester 2 problem. He gradually lost interest and became disengaged. He also duplicated his Semester 1 portfolio and submitted the same portfolio for assessment in Semester 2. This resulted in Edward failing PBL Subject 2.

5.2.2 Student 2, Ali

Ali was an African student who migrated to Australia while he was studying at high school. He worked part-time and decided to attend university with some of his friends because this was the norm for that group. He aspired to become a power engineer and obtain a highly paid job. In Semester 1, he decided to join a team which mostly consisted of students from his country of birth. Even though he felt comfortable in their company, he felt that working in a team with them was unmanageable. He was concerned that the majority of his team members including himself were having fun during most meetings and worried that this might lead to lower grades. Ali mentioned that he took his studies seriously, but at the same time he thought it was fair to have some fun.

> At the moment, I am enjoying this sort of life style as it personally suits me. I am also enjoying my course so far … it offers students a better life style

He expressed some difficulty in understanding the Australian higher education system and explained this as a consequence of growing up overseas up to Year 10. He saw transition to university as a learning task and expressed some concern about PBL:

> I don't understand this [PBL] stuff and that. I know it is about learning in a group and all that, but I don't really get what they [supervisors] want us to learn. I think it is the same as the other subjects [lecture-based] but with more practical work. But it's fun.

Considering himself brighter than other students in his team, he assigned himself the job of leading the team. Ali consistently used a surface approach to learning and solved the tasks that were assigned to him in isolation. At times, his supervisor was concerned about his progress and spoon-fed him with solutions to problems. As an example, during Semester 1, his PBL supervisor spent the scheduled meeting time solving sample test problems from another subject that was taught in lecture-based mode.

Ali attended unsupervised team meetings that were organised by Elias (another team member) during Semester 1. When Ali's team solved Problem 3 in Semester 1, most of the unsupervised team meetings ended up in clashes, both verbal and physical between Elias, Raja and Ali. Ali normally aligned himself with Khadir, another student from his country of origin, and strongly opposed ideas suggested by Elias and Raja. Ali indicated that his team members did not display any interest in understanding his contributions. He also raised concerns about a team member's stereotyped and often racially prejudiced views and reported that he always compromised to avoid arguments. For this reason, Ali worked with Khadir, leaving the rest of the team to work individually.

> To me if someone likes to take a role, I let them go. But, I don't like Elias. He is just too much. He doesn't understand where I come from and he wants to do everything by himself.

In Semester 2, Ali's contribution to the team was again superficial. He always picked tasks that he thought was easier than the others.

> I contributed a lot to the survey, to serve the priority and all that. The second one I did, even thought I didn't do the most, like the other groups … I did the digital fair enough, fair bit of it. Coz that's what I like and the other one [survey] is easier to me.

During team meetings, Ali socialised with his team members, including talking about his job, but made very little or no attempt to have subject-related conversations. He often used sexual references when conversing with his team members. He occasionally asked questions of his supervisor to clarify his doubts during supervised team meetings, but never shared ideas or explained the solution to his tasks to other team members. According to Ali, sharing of information was only meant to happen on WebCT. He advised that he shared information with his team members by posting messages on WebCT but indicated that he did not tend to read the messages posted by other team members.

Ali met with his team members face-to-face for less than an hour a week during the semester. Even though he was physically present for most team meetings, he tended to disengage soon after the supervised team meeting started. At the end of Semester 2, his view of PBL was that it was a subject where there was lot of written work designed to improve communication skills while some technology was taught as well. He also added that PBL helped him approach problem-solving by delegating tasks and locating information from different sources. While he located information from various Internet websites, he did not make any attempt to validate the reliability of the source of the information.

> Basically, it improves people's, engineering students', English, talking and communicating with other people and solving problems in different ways … like say different ways of researching like how we give tasks to each other you know. Our group would give each other tasks, like people choose normally what they are good at and then do it themselves.

To summarise, Ali entered university because he believed that young men of his age should pursue some form of university education. He preferred to socialise with students from his country of origin but was also receptive to team members who were of other ethnic origins. His intrinsic motivation was low and he used a surface approach to learning in PBL. He perceived that learning in a PBL setting would help him develop information literacy and oral and written communication skills, which in turn would help him manage problem-solving. He negotiated the tasks that he preferred to engage in and only worked to solve those tasks. Ali did not attempt to discuss or learn from the ideas of other team members. He displayed a high interest in creating an identity for himself in the team. He may have been encouraged in this by the attitudes and behaviours of the members in his team and by his supervisor.

5.2.3 Student 3, Jacob

Jacob was a mature age student of Asian origin. He studied full-time, but also worked full-time helping his parents at their family restaurant. He mentioned that he wished to provide a better life for his family through a highly paid job in electronics engineering and considered a degree in engineering a status symbol. In Semester 1, Jacob was part of a team where all of the students were of Asian origin. He took part in most of the team meetings and finished all his tasks on time in Semester 1. However, Jacob's contribution to the team was minimal. During Week 6, Jacob contributed to writing his part of the technical report in a computer laboratory that was set up next door to the PBL learning spaces. He complained that the computer facilities provided were not connected to the Internet and this limited his contribution to the tasks.

He only worked on tasks that were assigned to him. He took no interest in listening or learning from other team members. He took minutes of the team meeting once during the semester and other than that he did not take any other role. It appeared in team meetings that he was more interested in studying individually than in a team setting. He frequently appeared disengaged during team meetings and removed himself from the team as soon as the supervised sessions were over. During supervised meetings, he frequently changed the topic of discussion. After Week 7 in Semester 1, Jacob's work commitments took priority and he started to miss supervised team meetings. By the end of Semester 1 Jacob had missed three supervised sessions. Due to his absence, he was unable to submit his work for Problem 3 on time.

In Semester 2, Jacob returned to study in Week 3. He discovered that his previous semester's team members did not wish to accommodate him in their team. Jacob went to his course co-ordinator for help, who found him another team for that semester. Jacob seemed to struggle to understand the Semester 2 project. He appeared confused about the project but did not make any attempt to clarify it.

When the team members decided on the allocation of tasks, he did not show any interest in taking responsibility for a task. He expressed a preference for contributing to the programming task to simulate the intersection that the team had chosen, but remained passive as it was already shared by two other members. He did not make any attempt to contribute anything in the two supervised meetings that he attended. His only conversation in the team was to let his team members know that he was not studying the same lecture-based subjects as the other members in the team.

> Because I failed both the lecture-based subjects in the first semester, I am repeating those subjects in Semester 2. I am just letting you guys know, I don't do the fundamentals one, the programming, the digital and the stuff, yeah I don't do that one. I am doing the maths and the physics.

He clearly indicated that he was not willing to actively participate in working on the problem and excused himself from the team to attend classes for the subjects that he had failed in the previous semester. As engagement in a task was a requirement of the PBL subject, he eventually tackled the programming for simulating the traffic intersection on his own. He presented the programming and testing he had performed at the progress presentation in Week 5. During the progress presentation, he demonstrated a working model of the simulation by applying programming skills that he had developed elsewhere. But after the progress presentation, he absented himself from team meetings without notice. One of Jacob's team members, Bruce complained that Jacob had not returned his calls for weeks and only towards the end of the semester had he responded to a text message. Bruce later mentioned that Jacob had dropped out of the course due to ill health.

To summarise, in both semesters Jacob's work took priority over his studies. In spite of working full-time, he chose to study full-time because of a strong extrinsic motivation for gaining a qualification. He participated in team meetings in Semester 1 more than he did in Semester 2. It is possible that, he felt more comfortable with his team members in Semester 1 as they were of the same ethnicity. However, he only took minimal responsibilities and preferred to work on tasks that involved application of his prior knowledge. It is possible that he chose such tasks to minimise the effort required. In Semester 2, Jacob only attended a couple of supervised team meetings, did not engage in any activities supporting group processes or problem-solving process and discontinued without notifying his team members and his supervisor.

5.2.4 Student 4, Khadir

Khadir was a student of African origin. He did not speak much in the team even though most students in his team were from his country of origin. He always worked in conjunction with Ali and they were firm friends. He desired to "learn new things" and obtain good grades and thereby obtain a “good job”. In Semester 1, Khadir seemed to be overwhelmed by the experience of not having someone who taught him how things worked. He struggled to make his robot work in Problem 1, which was an individual task. He was unable to complete his work on time and asked for an extension to submit his work for this problem. He negotiated with Ali and obtained his help to make the robot work.

In Problem 2, he contributed by locating resources. He often provided his team with information that he found on the Internet, but without evaluating the trustworthiness of its source. Whenever he was asked questions by his supervisor, he mostly remained silent, put his head down and refused to give eye contact. He shared information with his team during team meetings only when he was asked by his supervisor to do so. On some occasions he answered questions on a superficial level. He always picked the tasks that he felt comfortable with and did not wish to take up tasks that involved deeper thinking and problem-solving processes.

Most of the time he required assistance in working on the problem and always leaned on Ali to help with the tasks that were allocated to him. However, when he reported on his progress, he opted not to disclose his reliance on Ali. During the presentation, he explained that it took a great deal of his effort to perform the tasks, while in reality he found tailored solutions on the Internet with the help of Ali. Khadir’s behaviour in Semester 1 was close to that of a freeloader.

Khadir’s behaviour did not change in Semester 2. He remained passive and did not engage in any activities. He seldom looked at the supervisor and concentrated on taking notes every time the supervisor suggested ideas to his team. He appeared to be restless during supervised team meetings and often moved his posture or his chair. He took up the task of locating information and often contributed unrelated information, which he posted on WebCT. Most messages that originated from Khadir were addressed to Ali.

In Week 11 Khadir brainstormed with his team in an unsupervised meeting to identify topics that were required for presentation. During this meeting, it was evident that Khadir’s aim was to perform well in the oral presentation and he proposed the structure of his team’s presentation. Khadir also submitted a portfolio which contained many tasks that were completed by other students in his team. He claimed to have contributed to surveying the intersection, circuit construction and testing, despite playing only a peripheral role in completing those tasks.

To summarise, Khadir had an extrinsic motivation to achieve high marks. He worked on tasks that he perceived were easy for him to manage. He displayed an interest in finding new information on the Internet, but did not suggest ways to use that information. He did not attempt to understand, validate or discuss his findings. Thus, he only acquired a superficial understanding of the problem and the process required to solve it. He often blocked communication and refused to co-operate with everyone else in the team except Ali. Khadir never socialised with the team and expressed a preference for lecture-based teaching and learning methods.

5.2.5 Student 5, Theo

Theo was an Anglo-Australian student. He transferred to the electrical engineering course after studying three years in another undergraduate course. Theo advised that he was referred to this course by a lecturer who had taught him in the earlier course. He aimed to complete the course and obtain an employment in the engineering field as quickly as possible but also mentioned that he realised that it would take him another three years to achieve this.

Theo displayed a good knowledge of the campus and showed his classmates around the campus on the orientation day. He was enthusiastic and cheerful about studying in PBL mode and expressed the opinion that he had a fair idea of how to participate in such a setting from his previous experiences. During the second week of Semester 1, Theo mentioned that his hunch about what to expect in the course allowed him to engage in other activities.

> So far this semester has been very entertaining and even though I had a small inkling of what to expect from this course due to previous studies with [Supervisor].

Attendance in Week 3 and 4 was crucial as this was when Problem 2 was delivered and targets were set for students to design, construct and test the amplifier circuit. Theo missed out on the entire problem as he was absent during those weeks. He put on a show of coolness and seemed not to bother about contributing to the team. He did not take up any team role and did not help his team members in finding a solution to Problem 2. During the progress presentation, his presentation slides were not consistent with those of the other members of the team. This substantiated the fact that Theo had not worked in conjunction with his team members. He advised his team members that he was absent for scheduled meetings because he had to attend to work priorities, without which he would be unable to finance his education.

> At first it was difficult trying to balance my work hours with university and study time, but that was mostly just due to the Commonwealth Games and a high percentage of secondary schools holding their holidays during that period. Now that it's over and I've had a chance to swap my days around, Mondays to Fridays can now be mostly dedicated to university life rather than work.

Theo started to take things more seriously when he received a warning from his supervisor for failing to attend team meetings. He took responsibility for researching the design of the battery system for Problem 3. After his brief apprehension about failing the subject, Theo once again became cool and started absenting himself from meetings and only attended a couple of meetings towards the end of Semester 1, just in time for the final presentation. During those meetings, Theo seldom contributed. He only helped his team members minimally and most of his contributions were of a minor nature such as fetching paper to print the team technical report, obtaining the components and handing them over to team members. His only substantial contribution was organising the presentation slides for the oral presentation.

In the beginning Theo's behaviour could be interpreted as that of a very shy person. However, towards the end it became apparent that his silence may have been a result of his superficial knowledge of the subject content and the problem. His aim was to pass the subject with minimal contribution and efforts. While he managed to pass the PBL Subject 1, he failed the other two lecture-based subjects.

In Semester 2, Theo joined another team. He mentioned that he made the choice to place himself in a team which aspired to perform rather than to complain about what was to be done.

> I changed teams because; I did not want to be with the same bunch of kids who have a pro high school mentality. They always venge and complain about me not contributing to the team.

In the new team, Theo appeared to be active for the first half of the semester. He contributed to the team during the survey by obtaining information about the traffic system from VicRoads[2]. He contacted an officer at VicRoads and obtained information through a Freedom of Information claim[3]. He approached certain parts of the problem with confidence and curiosity. Specifically, he volunteered to design a digital timing circuit to control the timing of the lights at the traffic intersection chosen by the team. He also displayed aptitude in using digital components such as flip-flops and counters, use of which was not attempted by other students at that time, perhaps because he had already studied digital electronics in his previous course.

After contributing to the initial problem-solving process, Theo was frequently absent from supervised and unsupervised team meetings and only attended alternative supervised team meetings in Semester 2. At supervised team meetings, he discussed his topic only when his supervisor asked him to do so. Theo seemed to be quite confident when presenting the parts of the problem that he worked on. He indicated that he approached the tasks allocated to him at a deeper level, but his contributions suggested a more superficial approach. He was never involved in sharing or discussing his tasks with his team members and he also made little attempt to understand the contributions of other team members. It was apparent that Theo was inclined towards taking shortcuts. He appeared to play the academic game by managing problem-solving at a superficial level and reporting the outcomes of his tasks to supervisors upon completion, thus creating the impression of being an active team worker.

To summarise, Theo socialised well with members of his team in both semesters. As he had previously studied at the same campus, he felt more comfortable than other first year students. He took shortcuts by planning his participation and presenting his ideas with confidence in both semesters to make it appear to his supervisors that he was an active learner. However, it was clear that he took a surface approach to learning and appeared extrinsically motivated to complete the course in the shortest possible time with minimum effort.

5.2.6 Student 6, Lucas

Lucas was an Australian student of European ethnicity. He entered the University as a school-leaver and wanted to find a "reasonably good job" at the end of the course.

[2] Vic Roads manage and control traffic system in Victoria, Australia.

[3] Freedom of Information Act 1982 provides access government documents upon payment of a fee.

Lucas was very silent and did not take part actively in the group processes. He appeared introverted and never showed any interest in socialising. He seemed to be serious and sensitive with little interest in having fun. He also put his head down for most of the time during team meetings. While he appeared to listen and process information during discussions, he seldom made a contribution or asked them a question. He conversed only when challenged by his supervisor and at times when he sought clarification from his supervisor. The following example is an excerpt from a video-recorded observation transcript of the learning interaction between Lucas and his supervisor.

> Lucas to Supervisor: How do we get the graph exactly?
>
> Supervisor to Lucas: Get one curve indoor, another one for outdoor.
>
> Lucas to Supervisor: Do we have to have indoor experiment set up for different light source? I mean a different light source for outdoor and different load.
>
> Supervisor to Lucas: Different load will give you different points.

Usually he left the team soon after the supervised team meeting was over. During unsupervised team meetings he clearly indicated with his body language that he disliked social chat and often blocked any communication initiated by his team members. In an informal interview Lucas stated that he was getting used to learning as part of a group but was unsure whether social chat was acceptable behaviour during supervised meetings.

> I am quiet because I normally am. I like working with my team members, but I am not sure if it is OK to be talkative.

Lucas only contributed to the tasks that were assigned to him. He was well organised with his belongings and always cleaned up his learning space after he finished using it. He completed the tasks thoroughly and well and earned appreciation from his supervisor for doing well. However, he struggled to present his ideas to his team members and only discussed his findings with his supervisor. His actions during the semester led his team members to label him as a homosexual towards the end of Semester 1. Lucas was offended by this and distanced himself from the team. He did not attend the last couple of team meetings but participated in the final presentation, leaving as soon as he finished his part of the presentation.

In Semester 2, Lucas approached his supervisor and asked to switch to another team. His supervisor then placed him in another team. In the new team, Lucas continued to be silent. At the beginning of Semester 2, Lucas appeared to be restless and anxious on many occasions. He left as soon as the supervised team meeting was over and struggled to maintain contact with the rest of the team members.

As the semester continued, Lucas's behaviour gradually changed. While he remained silent during supervised and unsupervised team meetings, his body language seemed to change slowly. He started to give eye contact to and to communicate with his team members and occasionally with the supervisor. He also started attending unsupervised team meetings. Lucas appeared to gain confidence slowly and contributed to the location of information for the team. When he collected information related to the topic that the team discussed during the week, he printed out a copy of his findings for every team member and passed it on to them. He expressed a preference for printing out his findings for each team member rather than explaining it to them. However, he did not make any other contributions to the work of the team. He appeared to have learnt to be just another team member just doing enough to get by.

In summary, Lucas preferred to work on his tasks alone. Although, he showed eagerness to learn, he only gained knowledge in the tasks that he completed. This is possibly because he lacked social skills and perhaps confidence. He blocked communication from other team members and therefore did not engage in discussion with them. It was apparent that he failed to develop generic skills such as communication skills, interpersonal skills and team working skills by avoiding full participation in the group learning environment. He displayed certain behaviours that led to his team members labelling him a homosexual in Semester 1. Offended by behaviour of his team members, Lucas joined a new team in Semester 2. He remained shy and passive in his new team and therefore failed to make the most of leaning in a group. Lucas adopted a surface approach to learning during both Semester 1 and Semester 2.

5.2.7 Student 7, Phillip

Phillip was an Anglo-Australian student who was a school-leaver, coming to university directly from secondary school. He was in the second year of the robotic engineering course but enrolled in the first year PBL subjects because they were now a compulsory part of that course. In Semester 1, Phillip was an excellent team worker but remained silent during most of the supervised team meetings. He provided support to others and worked alongside Bruce, another member of his team.

Phillip rarely made contributions during supervised team meetings but had no hesitation in expressing his ideas during unsupervised team meetings. Phillip possibly feared the questions that his supervisor might ask and hence adopted a low profile in supervised meetings. While Phillip preferred to listen rather than talk, he appeared to be concentrating during group-discussions.

When brainstorming in the team meeting at the start of Problem 2 in Semester 1, Phillip reflected on his previous problem-solving experience in a real life situation in which he helped his family members to fell a tree. He discussed the problem-solving process with examples of strategies that he used to tackle the problem with his family and called for his team members to reflect on similar situations they may have encountered and apply their experience to solving the problem.

Phillip met with his team members in Semester 1 as often as possible. He took the roles of scribe and event manager. He scheduled unsupervised team meetings and took minutes during every team meeting. He posted the minutes in WebCT before the end of each week to help team members reflect on their performance. In both Problems 2 and 3, Phillip made valuable contributions to the approaches taken by the team.

> Well, for the reports, my main area was the financials area. So like, with the amplifier, I had to compare prices, how much would it, like what will happen if we change some things. For example if the instruction manual is printed in colour, how much will that cost and would it be actually worth it or not. And, solar panel I had to compare prices like of the solar panel, like running a solar panel compared to like grid systems, like say coal or nuclear and compare prices with that. So that was my main input for the group.

Phillip expressed concerns that students were not formally given any training in producing a portfolio. He stated that by the time he discovered that it was important to understand the contribution of other team members; it was too late to learn about these contributions.

> Well, it was usually someone else's task, like mine was money and like the cost of the solar panel against the grid systems. I worked on that and found that grid systems are actually cheaper. Some of the stuff that we wanted to look up, we couldn't actually and that was the main problem. I didn’t get a chance to see what [student] did as I had to complete writing

> up my part of the solution. It happened in every problem and I know it is a problem. But, we have completed this, you know what I mean?

In Semester 2, Phillip provided substantial support to his team leader when most of his team members had dropped out. Phillip expressed frustration with the way his team was handled by the supervisor. He was one of the only two members left in the team and he worked hard with his team leader to complete the project. After Week 5, he participated in unsupervised meetings almost everyday and completed the design and construction of the controller system to the satisfaction of his supervisor.

At the end of Semester 2, Phillip expressed concern about the mix of lecture-based subjects and PBL subjects. He declared that the different learning methods were not only confusing but also frustrating because it was difficult to prioritise exams and assignments in the lecture-based subjects with deadlines in PBL. He advised that the amount of work required for the PBL subject left him with no time to concentrate on the lecture-based subjects and added that he feared failing those subjects. Even though the lecture-based subjects were intended to equip students with knowledge and skills required to solve the problems in the PBL subject, he pointed out that this almost never happened.

To summarise, Phillip was an excellent team worker. He was intrinsically motivated and approached learning by contributing and engaging in co-operative work with his team members. He sought meaning for new information that he came across while learning as an individual. He discussed his tasks and his findings with his team members, but did not criticise or analyse the ideas suggested by other members of his team. He thus became a passive listener and did not process information from other members in his team. He made sure he completed his tasks on time, but did not concern himself whether other team members had completed their work. He thought that it was his team leader’s responsibility to make sure individuals completed their tasks and he did everything that he was asked to do in order to make sure the team completed the problem on time. Although Phillip’s motive was intrinsic, the strategies that he adopted in PBL indicated that he generally used a surface approach to learning.

5.2.8 Student 8, Timothy

Timothy was an Australian student of European ethnicity. He attended school in Australia and had previously dropped out of university. He was a mature age student who had returned to study with considerable professional and life experience. Because of his professional experience in a related field, studying first year engineering subjects was comparatively easy for Timothy. The only subject in which he had difficulty was mathematics. Timothy aspired to become an expert in electrical engineering and wished to obtain a promotion in his existing job after completing the course.

In Semester 1, Timothy was very keen on identifying his learning needs; he was often seen in discussion with his supervisor regarding this. He initiated all subject-related conversations in the team and was the only person to ask questions of supervisors during team meetings. He was of a similar age to the PBL supervisors and his age and work experience probably gave him the confidence to initiate discussion with the supervisors, a confidence most other first year students lacked.

Two of Timothy's team members in Semester 1 were from a non-English language background. In fact one member had only recently arrived in Australia. It appeared that Timothy discriminated against these two students. In general, he only communicated with them if they initiated the conversation. He normally communicated only with one member (Mike) of his team who was of Anglo-Australian origin. During other times, Timothy mostly would apparently speak to himself or ask a question and wait for somebody in his team to answer. The majority of the conversations in which Timothy was part of with his team members were related to the problem and the tasks and these conversations happened during supervised team meetings or during laboratory work.

Soon after the formal meetings, Timothy would either go to the library or go home. It was unusual to see him socialising with other students on the university campus. Timothy had a desire to achieve and hence focussed only on solving the problem. He preferred to work individually but played the game by indicating that others were involved in solving the problems. During a supervised team meeting in Week 7, Semester 1, he discussed a circuit diagram with his supervisor. When the supervisor asked him where they had got the circuit diagram from, he replied that the team had just made it. But in reality, Timothy had designed the circuit individually.

> Supervisor: I am happy with what you have come up with here (points to the circuit diagram Timothy had drawn on the board before the beginning of the meeting). You need to indicate the type of battery you will be using. Specify the switch. How did you come up with the circuit?
>
> Timothy: We just made it now.
>
> Supervisor: Good. Hook this up on breadboard before you commit to this circuit diagram. Put extra stuff like LED to slow down the charging. Put a Zener diode to stop the reverse current flowing.
>
> [Students looked at each other in silence (unable to understand the concept)]
>
> [Supervisor notices that students are struggling to understand...]

Occasionally during team meetings Timothy played the role of a tutor. He would help Mike out when he had trouble in understanding how a circuit worked. Timothy also used Mike, as a sounding board when he wanted to think out loud about the concepts that he needed to clarify. Timothy, thinking aloud, would then say “That’s right, I know how to fix it” and then take action. He took most of the work on his shoulders and was very committed to finishing the work before the deadline.

However, his willingness to solve problems did not necessarily mean that he encouraged other team members to do some learning. By initiating the problem-solving process as soon as the problem was delivered, he gave little or no room for his team members to discuss about the problem or identify their learning needs. He clearly indicated to his team members and to his supervisor that his aim was to specialise in engineering problem-solving and learnt things that he thought was appropriate. This behaviour was evident from the conversation between Timothy and his team members in the electronics laboratory during Week 8 in Semester 1:

> Timothy: Here we go, now we are getting the same thing. Is this going to go up you reckon? How are you going to measure the current when we got no load on it? We need a low resistor to draw a really nice current. 2 ohms or 1 ohm. At the moment we are doing nothing. If we get 1 ohm resistor what sort of power is that. 12 divided by 1 so we’re getting 12 amps. 12 volts divided by 1 ohm resistance. 1.1 watts. There no way this bastard is going to give 1.1 watts. It’s going to draw a max out of this. We didn’t brain storm together. We did it in the last problem as well. We just jumped straight into it and went ‘all right we know’. And then we come across problems. We are continually fixing problems. That’s how we are learning man. We need to ask [Supervisor]. We are learning but.
>
> Mike: No he might ask us to find...

> [Smoke comes out of an electronic component as soon as Rajesh connected the circuit to the power supply. Team members laugh]
>
> Timothy: Come on what's that? (Timothy asked Rajesh).
>
> Rajesh: It is a resistor.
>
> Timothy: No it's a trimpot. Try with this. It shouldn't burn out. Let's put him in. Because, you know how to measure. Connect it in series. Give me that.
>
> Rajesh: Here we go,
>
> Timothy: We are able to draw. We are still dropping 0.2 milliamp is nothing. Yeah 0.2 milliamps into 12. What's 0.2 milliamps into 12? 200 milliamps. That's by 12. Awful mathematicians you are all. It's at most pressure on me, man. It is dropping because it is not charged well. The solar panel can give us. So we can only run at 2 volts, not higher. Takes the batteries out (Timothy instructed Rajesh to take the batteries out).
>
> Timothy: Let's build this and order some more parts.
>
> [During the entire time the team was in the laboratory, Arjuna was listening to music on his MP3 player. He was clearly not interested in engaging with other students to conduct the experiment.]

It was evident from many conversations that Timothy was not interested in building a strong relationship pattern with members of his team. He was only going along with them to complete the requirements of the subject. During an individual interview in Semester 2, Timothy indicated his preference for individual work over teamwork to solve engineering problems during an informal interview at a student's (Claire) birthday party.

> Researcher: How is it going this semester?
>
> Timothy: Honestly, I am stuck. I would have completed the whole problem in three weeks if I were working on my own. I like the idea of working as a team, but anyway I am doing everything in the team. It's just taking so much time with so many people in the team. It's [PBL] a good idea but it's not implemented well. I reckon I will be fine if I am by myself.

He also learnt shortcuts and was prepared to manipulate the assessment system by giving his team members a superficial idea of his solutions when he discovered that PBL required students to work as a team. He did not see it as his responsibility to educate his team members.

In summary, Timothy was a self-directed mature age student. He generally appeared to use a deep approach to learning. However, he was also focussed on the producing a solution of high quality in order for him to achieve high grades, as he perceived that high grades would enhance his career options. Therefore, he was continually engaged in determining what was required was required for a high grade from when the problem was delivered. This indicated that he used an achieving approach to learning. Timothy completed most of the problem-solving tasks individually and did not involve other team members in the project. He rarely socialised and engaged only in subject-related conversation during team meetings.

5.2.9 Student 9, Claire

Claire was an Anglo-Australian mature age student. She was a very enthusiastic and willing student with varied interests. Participating in a team environment was second nature to Claire. She mentioned that her love for learning was her main reason for taking the course. However, she also believed that learning engineering would enhance her career prospects. Her outgoing nature allowed her to easily adapt, empathise and mix with most people including students in other teams, members of the teaching staff and other staff members. She invited students from other PBL teams and the researcher to her birthday party, thus providing an opportunity for more informal interviews with students.

Claire motivated her team members to work on tasks that were of interest to them. After the team brainstormed problems and the tasks to be allocated, she asked each member of the team to select a preferred task before she picked her own. She played the role of a mentor to Cathy, who had trouble organising references. She also occasionally helped Sasha in selecting her tasks. Before the end of every meeting she explicitly reminded team members of the date and time of the next meeting and reconfirmed the tasks of each team member. Throughout the year, Claire’s management expertise was demonstrated in the way she managed the tasks and her team members. She led the work of her team, composed team reports for Problems 1, 2 and 3 and managed tasks throughout.

> … Even though Rod took the responsibility of testing and construction in Project 3, a majority of the work in each project fell on to me. Much of my input was involved in putting together the report. It involved writing the introduction and conclusions as well as formatting the research produced by other team members to produce literature reviews and internal referencing as required. I also organised the testing for Project 2, referencing and structuring of our presentations.

During an interview Claire mentioned that micromanaging her team members during both semesters became her primary task.

> The truth is I'm terrible at letting others take the lead. As much as I like to pass the pressure onto others, I can't bear to keep quiet if I can see a better way of doing something. This continuously leads to my bossing people around whether I'm in a leadership role or not.

Yet, she claimed to dislike the role and wanted someone else to take the lead. Using her excellent communication skills, Claire persuaded Rod to take up the leadership role towards the end of Semester 1.

> I spoke to Rod privately about my conduct towards the team and asked him to put me in place when I was too demanding of the team. Rod didn't think this would be a problem but agreed nonetheless … I handed the leadership for Project 3 to Rod.

She then worked alongside Rod to learn technical knowledge from him that she lacked. Claire possessed clear self-awareness, a willingness to learn and also appreciated the contributions of other team members. She split each problem into many individual tasks and divided them among team members, often in unequal proportions. At the end of Semester 1, she collated the individual contributions of team members and produced the team reports for each problem, which were essentially a mosaic of individual contributions.

> Despite my bossy disposition, team members often thanked me for the work I put in and my organisation skills utilised to see the projects completed. My business-like attitude became a joke among team members … "I'm not worried if I pass or fail, I do the work because I'm scared that Claire will kill me if I don't".

In Semester 2, Claire took on responsibility for organising the team work, deciding on the tasks and allocating them to team members on the basis of her perception of their capabilities:

> Yeah, I basically try and delegate tasks appropriate to who is most capable of doing what ever task

In the first two weeks of Semester 2, she split the problem into technical and non-technical aspects and assigned most of the technical aspects to Rod. After taking responsibility for circuit design and construction during Week 3 of Semester 2, Rod started to absent himself from supervised team meetings. Rod's absence had significant effects. Tight deadlines and spectacularly misguided hypotheses brought arguments and disagreement between Claire and David, another team member. She reported in an interview that problem-based learning was just a waste of time and that, because of tight deadlines, it was impossible for team members to learn everything while solving the problem. She also complained about the lack of access to PBL learning spaces which resulted in fewer face-to-face team meetings.

> Simply given the time restrictions, there is not much. We don't really have room for, OK, let's all do this together, let's all contribute. You don't have time for that kind of thing. Which means people miss out on the learning aspect of it, I guess. If they don't get the project done, then it’s a waste of everyone's time.

David did not like Claire leading the team and told her that he had to take over because she was a woman. Claire found David’s comments insulting and sexist and she reacted in a couple of emails before offering to step down. However, she promised to complete the tasks that she had assigned herself. After, many telephone conversations with concerned team members and an apology from David, she started to actively participate in meetings again.

She explained that she had to take up the leadership position in the team because she believed that the rest of the team members did not have the natural ability to lead. Claire expressed frustration about the lack of support from supervisors in Semester 2 and complained that assistance was only offered when students struggled with the problem-solving process. She also complained that the problem brief was inadequate and that the unit outline was not distributed until Week 4, a week before the first progress report was due.

Towards the end of Semester 2, Claire became more dissatisfied with her PBL experience. She formally complained to the Head of School that PBL was the only learning environment that she had encountered where the projects seemed to be designed to create a feeling of incompetence and failure in the students before they even commenced. She demanded a review of the implementation of PBL and stated that the level of disorganisation and thoughtlessness in its structure was unacceptable.

Claire also complained about the assessment system for the PBL subjects. She was surprised that she obtained a Distinction for the PBL subject in Semester 2 because she believed that her performance was only worth a Pass. On the other hand, she noted that she had been given a High Distinction for her portfolio in Semester 1 but a similar portfolio had only yielded a Distinction in Semester 2.

To summarise, Claire was a mature age student who was personally committed and deeply motivated to study electrical engineering. In Semester 1, she was very enthusiastic and self-directed, organised team work and motivated other members of the team to work co-operatively. She took a leadership role and directed the group processes and the problem-solving processes for all the problems in Semester 1. She evaluated the ideas of team members for the first two problems and reported that she realised the importance of group discussion. Most of the times during Semester 1, Claire's strategies and learning behaviours indicated that she adopted a deep approach to learning. However, towards the end of each problem, she concluded that the timeline to complete the problems did not support collaborative work and therefore focussed on maximising the chances of completing the problems. It was also becoming apparent that she focussed on maximising assessment returns rather than maximising learning from the problem-solving experience. In Semester 2, Claire faced a challenge to her leadership apparently based on sexism. She responded by standing down from the leadership role.

5.2.10 Student 10, Matt

Matt was an Anglo-Australian student who migrated from a country town in Victoria to pursue his career aspirations. Matt was excited because he was the first one in his family and in the street where he lived to study engineering. He stated that he was also excited about studying engineering because when he finished studying he would be the first engineer in the street where he lived. He aspired to become a successful engineer.

Matt worked part-time on Mondays to support himself financially and also received financial help from his parents while he studied. He felt disadvantaged working part-time because he missed out on the support classes and workshops that were scheduled on Mondays. He had strong motivation to achieve academically as well as personally.

Matt studied a vocational education course in electronics engineering prior to joining the undergraduate course. Because of his previous exposure he possessed a better understanding of electronic components and circuit theory than most first year students.

He was proud of his skills and expressed a desire “to build on his professional status”. He automatically became the leader of the team.

Matt organised the teamwork and delegated parts of the problem to team members. As he focused on completing the task and achieving a high grade, he ensured the problem was completed thoroughly by paying attention to the smallest detail required by the supervisor. He assumed that the focus of the problem-solving task was achieving the target solution, which on most occasions was an open-ended example introduced by his supervisor.

Matt proved a tough leader. By the middle of Semester 1, when some of the team members absented themselves from meetings, he announced that he would not be repeating himself to them if they missed attending the meetings. He demanded that everybody in the team take equal responsibility and contribute to the team’s progress. But he only managed to obtain the help of one team member in the problem-solving process and ended up doing most of the work himself for both Problems 2 and 3 in Semester 1.

In Semester 2, Matt ejected two uncooperative team members from his team. Then in their place, he recruited four new students that he had befriended in the previous semester. As the size of the team had expanded, Matt realised it was impossible for him to manage the team and solve the problem at the same time. Hence, Matt shared the leadership role with another student in his team.

Consistent with his approach in Semester 1, Matt avoided sharing responsibility for problem-solving with his team members. Based on his perception of the tasks that were allocated, Matt always picked the ones that he assessed as the most sensitive part of the problem and the tasks that required expert knowledge. He only explained his solutions to team members who were his personal friends. During supervised team meetings, Matt volunteered to answer questions raised by the supervisor about the problem-solving process. He used the language of the subject while answering the questions, which indicated that he adopted a deep approach to learning. However, his approach to the process indicated that he was motivated towards achieving.

An example of Matt's achieving approach was the "PBL party" video[4] that he produced to maximises his chances of obtaining high grades. Matt persuaded his team mates to act in the video and used it to provide evidence of teamwork, while actually the team had done very little work together. Matt played this video during the final team progress presentation in Semester 2.

> We had an oral presentation and we couldn't be bothered studying. So we decided to just report the random stuff and then it became that.
>
> So you actually presented that video in your oral presentation?
>
> Yeah. Well we figured also, my theory is especially when you know who your examiner is - someone like [supervisor] who sort of likes fun. If you can make some one laugh, you have got more chance, like make them happy and enjoy the presentation and you have more chances of getting a better grade anyway.

In summary, Matt played an influential role in his team. He disliked sharing responsibility and wanted to be the leader of the team in both semesters. He directed and regulated his learning as well as his team's learning and only assigned tasks to members based on his perception of their capability. He delegated tasks to himself that were more difficult and that involved deeper learning and thinking processes. He decided on the members of his team and included only those whom he thought would support him in Semester 2. Matt always aimed at achieving high grades and hence decided to manipulate the assessment system by showcasing misleading evidence of effective teamwork. This indicated that Matt started off using a deep approach to learning but turned his focus on completing the problems and the project to maximise his grades and therefore adopted an achieving approach to learning.

5.2.11 Student 11, Bruce

Bruce was an Anglo-Australian student who had joined University straight after secondary school. Bruce mentioned that he wished to become a specialist engineer like his father. Like Phillip, he was different from most of the other students studying the PBL subjects because he was in the second year of the Robotic Engineering course. However, Bruce had already completed the other first year subjects offered in lecture-

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[4] The details of this video and the circumstances that led to its production are explained in detail in Chapter 6.

based mode in the previous year. Hence, his knowledge of electrical fundamentals and computer programming was also superior to that of most other first year students.

Bruce took several different roles in his team. In the first problem, he took the role of a scribe. He took the minutes of supervised meetings, took notes when the team brainstormed and also prepared an agenda template in Week 2. He advised that, according to his understanding, problem-based learning was intended to create an environment similar to an engineering work place. He stated that PBL gave him the chance to learn research skills that were not developed in lecture-based mode. He also declared that he learnt time management skills in the PBL subject:

> What I found was they didn't give you like very much information at all about the topic. They gave you the like main points about the topic but there were no actual information. You had to do all the research yourself. You just got to research more instead of getting taught. You just got to make yourself on it.
>
> I was like research it for an hour, hour and a half and I wasn't getting anywhere and then, I was writing a different section and then I sort came across this one website, and it explained really good so, just went off from there. The time varies a lot more than what it would in the lecture. It could take a lot longer, sure like what happened to me, it had taken quite a bit longer but then, I struggled to cross it and then it became shorter

He mentioned that he enjoyed applying theoretical knowledge that he gained in his first year to solving problems in the PBL setting in his second year.

> Yeah, it's lot of fun. You get to build it to start off with. Then you actually like know what you are researching about. And then you can relate it back to what you are actually learning about. You are learning about things that are not just theories and stuff.

Bruce reported that he felt motivated and obligated to perform every time he was delegated a task. Bruce took the role of team leader in Problem 2 in Semester 1. He urged his team members to take on tasks that they were interested in. On many occasions Bruce worked extended hours to complete his tasks. He moved on and took on additional tasks as soon as he completed his current task. However, he always worked on these tasks alone. The following excerpt from an observation log indicates how Bruce took pride in locating information relevant to the tasks of other team members. He passed that information to his team and felt elated about accumulating evidence that could be included in the team's report.

> Bruce to Phillip: Hey Phillip, look at this one.

> Phillip: What?
>
> Bruce: I found this thing about the cost involved in installing solar panel at homes
>
> Phillip gets up from his chair and moves to where Bruce is seated.
>
> Phillip: Sweet. Can you send it to my email?
>
> Bruce to Phillip: See, you guys should be proud of having me in the team. You could make the whole report out of this.

For Problem 3 in Semester 1, Bruce stepped down from the leadership role to allow other team members the opportunity of leading the team. He took the role of a team worker instead. After completing his tasks he organised the technical report by collating the contributions from all the members of the team. Bruce took this opportunity to analyse and evaluate the ideas of other members before incorporating their solutions into their final report. He carefully interpreted the solution by discussing and critiquing his team members' ideas and validated his perceptions by restating and reflecting.

In Semester 2, Bruce again took the leadership role in his team. He generated creative ideas for conducting a survey for the traffic intersection problem. He brought his video camera to record the intersection during peak hours and non-peak hours and later analysed the data to statistically determine the traffic flow at the intersection. From Week 1, he showed enthusiasm for solving the problem and mentioned that he had a better understanding of PBL than he had in Semester 1. While his aim was to produce quality work by working in conjunction with the members of his team, he was uncertain about the team's performance because of the variable attendance of the members of his team.

> For instance, Rodney, he was doing the traffic lights in "Borland" and I was doing a bit also on "Borland", so once he finished the traffic light, we got our two solutions of "Borland" and put them together to make like a really, really good solution to that problem, so sometimes they cross over and we have to talk about stuff. Otherwise, it is pretty much individual so you go and do your own research.

Bruce struggled to delegate tasks to his team members because of their unpredictable attendance. In Week 5, his supervisor split the team into two as the total number of students in the team was higher than of other PBL teams. By Week 6, two members of his team dropped out of the course and his team was reduced to just two members, himself and Phillip. Despite the sudden reduction in the size of the team and the increased effort required to solve the problem, Bruce demonstrated courage and commitment in the way he managed the problem-solving process. He decided to share the unfinished tasks with Phillip and motivated him to continue working hard. He applied his programming knowledge to develop a sophisticated working software simulation model (an exact replica) of the intersection. He also contributed to preparing the technical report for the project in Semester 2. He made extensive use of Microsoft Outlook to organise his work, including using reminders to complete tasks.

> I guess I just put it on my schedule. I got a little calendar thing.

Bruce continued to work on improving the software code he had written to simulate the intersection his team had chosen. He mentioned that he preferred approaching the support class lecturer who taught programming when he needed clarification in programming using “Borland C”. He complained that his supervisor’s efforts to clarify doubts often ended up in spoon-feeding.

> He goes to some extent a bit of spoon-feeding if you know what I mean. Yeah, you can sense a bit of spoon feeding. Because he is basically telling us what to do almost.

As Bruce spent all his time in developing the software program, he did not engage much in designing the control circuit. However, he discussed it with Phillip to gain an understanding of the circuit and also helped Phillip to test and upgrade the design to include all the minute details that they had observed in the actual intersection. Bruce mentored Phillip in his use of the software program and assigned simple programming tasks to Phillip.

He also contributed to the construction of a physical model of the intersection, in which he connected the circuit and the lights to replicate the traffic intersection. Towards the end of the Semester 2, when he ran out of time preparing his portfolio, he decided to submit his previous semester’s portfolio with appropriate amendments to the appendices. During a focus group interview, Bruce mentioned that the leadership role he took on in both the semesters gave him great satisfaction.

In summary, Bruce was a hard working, self-directed and highly motivated student. He managed the team’s work and worked on improving the solutions that each team member contributed. He took various roles in Semester 1 and also contributed to leading the team for the Problem 2. Bruce enjoyed organising the group processes and was proud of his time management skills. He carefully interpreted the solution by discussing and critiquing his team members' ideas and validated his perceptions by restating and reflecting. He was very creative and contributed to strengthening the ideas of other team members. He motivated his team members, mentored, shared ideas and led the team towards successful completion of the problem-solving process in Semester 2. Bruce's learning motivation and the strategies he adopted in PBL indicated that he used a deep approach to learning.

5.2.12 Student 12, Jeff

Jeff is an Australian student of South African ethnicity, who entered university from secondary school. He reported that he had previously attended schools in South Africa and New Zealand before his family decided to migrate to Australia when he was in Year 7. He believed that a university education, in particular an engineering degree, would enhance his employment prospects. He considered higher education because his parents had asked him to continue studying after high school and assured him of their support while he studied. However, he mentioned in the beginning of Semester 1 that he was unsure which specialist area in engineering he should choose. He said that he was trying out electrical and electronics engineering as an option. At times he also mentioned combining an arts or a management degree with his current course because he believed that in the end there were better employment opportunities for graduates in multiple disciplines.

> I took up engineering because my parents said they would support me financially. I also wanted to try out this one [electrical and electronics engineering] because, I don't know may be there is better chance for finding a job in the end.
>
> …I am also considering taking on board the dual degree option coz it might boost my knowledge in management or an arts degree you know

Due to his focus on employment, Jeff was keen to obtain high grades. He explained that his supervisor had told him that his team's success was his success and interpreted this as meaning the pathway to obtaining a higher grade in the PBL subject was to make a successful team. Consciously or unconsciously, he took the lead in making sure information was shared and was processed by everyone in the team. He learnt with others as well as individually.

Jeff believed that the team's performance would drop if there was poor communication within the team and because of this he did his best to ensure the team's morale remained high by communicating with all members continuously and professionally. In an individual interview Jeff said that he gave his team members equal opportunity, never discriminated between his team members and never commented on anybody's capability. He advised that, on some occasions, he had to assign tasks to his team members in order to keep the project moving.

> My team got on well. There were no barriers of personality, gender, race, religion, status and differing views. I tried to give good feedback to the team where deserved and used a friendly tone with the team while still being professional. I also tried to keep the team informed on exactly what needed to be done, while allowing the team to choose what they feel comfortable with. If no one chose a task I assigned the task to a team member to keep the project moving.

In both semesters he normally chose his own tasks and made sure he completed all of them well in advance. He also worked on finding alternative methods to solve a problem and came up with more than one solution to every task that he handled. Interestingly, the solutions generated by his team were often not considered by other teams and sometimes surprised supervisors, who praised the team for being innovative.

In Semester 1, Jeff reported that his quest was improving his own technical knowledge and skills. He added that he also understood that the essence of PBL was to develop his generic skills. After being advised early in the semester that his success depended on his team's success, he spent an increasing amount of time with his team members discussing the progress of allocated tasks and making sure they were all up-to-date with their work. He explained research findings and technical content to his team members often in one-on-one and face-to-face meetings. Occasionally he also played the role of a tutor in helping team members who had difficulty in understanding technical concepts. Jeff organised his team by making sure that all members had their opportunity to discuss and learn from the individual tasks performed by each member. The following is an excerpt from his portfolio:

> Organisation is important in a team and I believe that I have achieved this successfully. I made an action plan for the team to follow and I informed and organised the team to do tasks. Preparing agendas is important for meetings to be effective. I wrote up all the agendas for the meetings. I organised questions for discussion into topics for clarity of reading and understanding. My team successfully completed each of the deliverables set

> out for them and we together made up the complete project to prove that each of the deliverables was completed on time.

In Semester 2, Jeff's supervisor called for a vote to elect the team's leader and Jeff was elected to lead the team. Being the team leader he decided to allocate the tasks in the traffic automation project equally in such a way that each team member had the opportunity to contribute to the survey of the intersection, to coding the simulation of the intersection and to constructing an electronic circuit to control the traffic intersection. This did not happen in the majority of the other teams, where individuals carried out the survey, designed the software model, constructed the circuit, composed technical reports and often had no time to discuss or learn what the other members of the team had done.

In the middle of Semester 2, Jeff volunteered for and participated in the official opening of the new PBL learning spaces (studios). He used his opportunity to demonstrate yet another learning outcome in his portfolio - Demonstrate professional engineering skills:

> I used the opportunity to be a good representative of PBL and to demonstrate what I have been studying so far from the beginning of the first semester. This experience is equal to being a good representative of a company and conducting myself in a professional manner as part of a company.

He was mostly happy about his experience of learning in PBL, except when some of his team members refused to co-operate with his schedules because of their paid work commitments. On such occasions he took the initiative to meet with them individually and also to regularly communicate with them by phone or email. Jeff valued every team member's contribution to his knowledge development process. He carefully sampled and tested information passed to him by his peers and provided feedback to them where he felt it was necessary. He provided constructive criticism to his team members and sorted out differences of opinion at the team meetings. He explained that he had become more independent by the end of the semester and that he had not only learnt about programming and digital electronics but also thoroughly learnt about being a leader and a team member. He claimed that leadership was a difficult and lonely task and expressed a preference for being part of an active team with strong relationship between team members.

To summarise, Jeff was deeply motivated and aimed to secure a well-paid job at the end of the course. During both Semester 1 and Semester 2, Jeff was committed to achieving high grades to enhance his chances for employability. As he perceived that his team's success was his success and a pathway to achieving high grades in PBL, he encouraged his team members to actively participate and contribute to the PBL process. He made the subject material meaningful by putting it into a practical context and continually worked with his team members to discover more than one solution to every problem. He delegated tasks equally to all members in his team and discussed the tasks and the solutions face-to-face and often one-on-one with his team members. He perceived, processed and provided feedback to the solutions suggested by his team members and also accepted suggestions and feedback provided by his team members for his ideas. The strategies that Jeff adopted in PBL indicated that he used a deep approach to learning in this setting, though perhaps his motivation was to achieve high grades.

5.3 Learning approaches

As expected in most undergraduate courses, most students had entered this course soon after some form of secondary education. Some were mature age students, which is common in Australian universities. Both groups face transition challenges as they move into a tertiary education setting. While it is normal for students to feel somewhat alienated by the new university setting, PBL seemed to escalate the confusion in many students' minds and this was reflected in their approaches to learning.

Analysis of the data collected for this study indicates that the students' views of PBL were essentially positive. Most students who participated in this study expressed a willingness to participate and learn in the PBL context as PBL gave them the opportunity to take ownership of, to control and to regulate their learning, for example, Matt, Jeff, Bruce, Phillip and Claire.

The students displayed an awareness of the different roles that they needed to take in PBL. Some students were willing to take on multiple roles, but many retained the roles that they assumed in the beginning of each semester, e.g. Timothy, Matt and Jeff. They generally displayed some commitment to learning generic skills such as delegating tasks among team members, managing problem-solving and learning to meet deadlines. Understanding these processes is important for students learning to work in groups and most appeared to gain some understanding of these processes. However, only those students who were willing to take responsibility for their own learning fully contributed to the PBL process.

As discussed in Chapter 2, the literature strongly recommends the use of active teaching and learning methods to promote deeper approaches to learning. It is argued in the literature that problem-based and project-based methods provide an environment that encourages a deep approach to learning (Biggs, 2003). However, it was found that most students in this PBL setting adopted a surface approach to learning. It was apparent that many of these students were extrinsically motivated and engaged in gaining a qualification rather maximising their learning. They therefore focused on completing their individual task with minimal efforts, thus adopting a surface strategy. Because of this, they did not tend to see interconnections between their task and the tasks of their fellow team members. They also appeared to not bother much about the meanings or implications of what was learned. Edward, Ali, Jacob, Khadir and Theo are examples of students who used a surface approach to learning.

On the other hand, it was found that students who consistently used a deep approach to learning were intrinsically motivated. They were curious, sought meaning in what they learnt and had a personal commitment to learning. A few students related subject material to personally meaningful contexts or to existing prior knowledge. Claire, Matt, Jeff and Bruce are examples of students who regularly adopted a deep approach to learning. There were many instances when Jeff and Claire searched for analogies for their newly acquired knowledge. Matt was also observed relating problem-solving tasks to his previous knowledge. Claire's portfolio provided excellent evidence of what she perceived she had learnt through PBL. Jeff constantly looked for alternative solutions thus deriving extensions and exceptions.

Although Claire and Matt had deep motives for their learning, their interpretation of what PBL required appeared to influence their strategies towards achieving an approach. It is also possible that the roles that they assumed in their team and the tasks that they preferred to handle encouraged them to focus on solving the problem on hand with a view to obtaining a high grade.

Timothy clearly focussed on the quality of the product. Although he assumed roles that involved optimal engagement in the task, similar to the deep approach, his engagement appeared to be a means to achieve high grades. Students like Timothy and Claire, who were hoping to learn technical knowledge and skills, were disappointed and felt that PBL was badly managed by their supervisors or the School. These students explained that they expected some implementation problems in Semester 1, but blamed the School for not adequately planning the curriculum and its implementation in Semester 2. As illustrated in the accounts of the students presented in this chapter, the ways that they approached learning in PBL were influenced by their attitudes and behaviours and by factors in the learning environment.

5.4 Summary and conclusion

In this chapter, the three sub-questions of the first research question stated in Chapter 3 have been explored by identifying individual student attitudes, behaviours, and their approaches to learning in a PBL setting.

Data collected about twelve students were analysed systematically by searching and rearranging the field notes and the transcripts of video-recorded observations, and the transcripts of individual and focus group interviews. It was found that individual student attitudes towards group learning influenced their behaviour within their teams; their individual behaviours while learning as a team influenced their approaches towards learning in PBL and their individual learning approaches influenced their learning outcomes.

It was found that most of the students in this sample adopted a surface approach to learning rather than a deep approach that PBL purports to encourage. This may reflect the learning context of this implementation of PBL. It is possible that aspects of the learning environment, for example the course structure, the teaching methods used by supervisors and the assessment system influence their perceptions of what was expected of them in this PBL setting. However, it was evident that the individuals making up a PBL team had a strong influence on what is learnt within that team. Some individuals strongly influenced the behaviour of other members of their team and their perceptions of problem-based learning and group learning.

This chapter focussed on individual students and it should be remembered that the learning approaches identified are the approaches taken by individual students. However, the learning approaches adopted by the individuals in a team no doubt determined in part the learning culture of that team while the learning approaches of the individuals who were its members at the same time influenced the learning culture that developed in that team.

The theory of reasoned action discussed in Chapter 2, emphasises the influence of attitudes on behaviours and provides a foundation for addressing the way individual attitudes lead to individual behaviours and then to individual actions. If the normative beliefs of students concerning teamwork are added to this, it may be possible to shed some light on how students form a successful or unsuccessful PBL team.

To be precise, both the normative beliefs of a student when he/she is under the direct supervision of a staff member and the normative beliefs of the same student in the unsupervised PBL team activities deserve consideration. Factors such as authoritarianism, introversion-extroversion, sex, age, social class, race, social role, status, socialisation, intelligence and relationship patterns must also be considered.

The individual student factors such as age, prior engineering experience, confidence, paid-work and participation and the attitudes and behaviours of individuals towards their team members including racism, sexism, individualism, collectivism as well as approach to learning identified in this chapter had an impact on the learning cultures that emerged in the PBL teams in this study.

These factors will be explored further in Chapter 6, which focuses on the learning cultures that developed in the PBL teams in this study. It examines the ways in which these individual students approached learning as a team, the way they directed and controlled their learning as well as the learning of other members of their teams and the way they influenced the group processes of their team and roles assumed by their team members.

Chapter 6

The team: Learning cultures

6.1 Introduction

In the previous chapter, the ways in which individual students approached their learning in a PBL setting and the ways in which their attitudes and behaviour influenced their approaches to learning were explored. It was evident that individuals in the teams had a strong influence on what is learnt as a team. Some also had an influence on the behaviours and learning approaches of other members in their team and their perceptions about problem-based learning and group learning. These ideas will be discussed and presented in detail in this chapter.

The main aim of this chapter is to describe the different learning cultures adopted by student teams in this PBL setting. As explained in Chapter 5, it was expected that analysing the shared beliefs and responses of students to learning as a team, that is the ways in which students in a PBL team behave, contribute and interrelate with members of their team and the ways in which they approach and direct their learning as a team will provide an insight into different learning cultures in PBL teams. In this study, "learning culture" means the shared approach to learning that develops in a PBL team arising from the attitudes, behaviours, actions and beliefs of the members of that team.

Jaques (1992) suggested that teaching and learning in small groups allows students to negotiate meaning, to express themselves in the language of the subject and to establish a more intimate contact with teachers thereby helping students to develop instrumental skills such as listening, presenting and persuading. As the team develops maturity and ability, relationships establish, and leadership styles evolve (Tuckman, 1965). Belbin (2007) identified a model of team roles that underlie a team success.

While theories such as these informed the analysis of data presented in this chapter, attempts have been made to identify the different learning cultures that developed in PBL teams and relate them to key attributes such as team membership, group processes, team leadership, individual learning approaches and approaches to PBL as a team. The learning culture that develops in a PBL team emerges from a combination of interrelationships between these and other factors.

As explained in Chapter 3, the data presented in this chapter were gathered over two semesters by various methods including observations, individual interviews, focus group interviews and student portfolios. Data were analysed by simultaneously reducing the data, displaying the summarised data and drawing conclusions from the presented data (Miles & Huberman, 1994). Firstly, data collected from interviews and video-recorded observations were transcribed. Video-recorded observation transcripts were then merged with field notes taken during observations to form an integrated observation summary. The transcripts of interviews and the integrated observation summary were coded and clustered using the NVivo software application. It is recalled here that the categories and sub-categories that emerged during the coding process were called attributes and dimensions in this dissertation. In this chapter, the codes that are used to explain the findings are referred to as elements.

After the coding process a description (narrative) of each team was generated by systematically searching and arranging the codes and the data that they described. Narratives of eight PBL teams are presented in this chapter. Further, the narratives were manually recoded and clustered to check and refine the attributes and dimensions that emerged during the analysis phase. Cross-case analysis was performed to identify similarities and differences between these attributes. Teams exhibiting similar traits were clustered together and an appropriate term was used to describe the emergent learning culture. Three different learning cultures emerged through the cross-case analysis. The common attributes that define each of the different learning cultures that emerged through cross-case analysis are also presented in this chapter.

Accordingly, this chapter is divided into two sections. In the first section, the learning cultures adopted by PBL teams are discussed by presenting narratives of eight PBL teams in which the twelve students discussed in Chapter 5 were members. These narratives are organised and presented according to the learning culture that the teams adopted. The learning cultures identified represent a hierarchy in terms of both their complexity and their support for effective learning. The three learning cultures are explored below in the order of this hierarchy – from least complex and least successful in supporting learning to most complex and most successful in supporting learning. The narratives of teams presented in this chapter describe the membership of each team and the group processes, team leadership, individual learning approaches and the team's approaches to PBL.

In the second section, the key elements that influenced the learning culture adopted by each PBL team are discussed according to attributes and dimensions from which they were analysed. The summary and conclusion to this chapter provides of a synthesis of the learning cultures adopted by student teams in PBL.

6.2 Learning cultures

The literature suggested many interpretations of the term "learning culture". In Chapter 2, it was reported that it is used predominantly in the organisational learning context. In this study, the idea of learning cultures has been approached as a holistic collection of practices emerging out of the attitudes, beliefs, behaviours and approaches to learning of the members of a PBL team, which influenced their learning in that PBL team.

Through cross-case analysis it was found that the PBL teams fell into three groups and therefore three different learning cultures that were adopted by students in their PBL teams were identified. These learning cultures are:

- Finishing culture
- Performing culture
- Collaborative learning culture

From the analysis of the data, it was evident that these different learning cultures in PBL teams were consciously or unconsciously shaped by students through their participation in the activity.

In this section the different learning cultures that emerged in eight PBL teams will be defined and described. The members of these eight teams are presented in Table 6.1 below. It can be noticed that the twelve students who were described in Chapter 5: Edward, Ali, Jacob, Khadir, Theo, Lucas, Phillip, Timothy, Claire, Matt, Jeff and Bruce are members of these eight PBL teams.

Table 6.1 Team members of eight PBL teams

	Team 1	Team 2	Team 3	Team 4	Team 5	Team 6	Team 7	Team 8
Semester 1	Ali	Edward	Lucas	Timothy	Claire	Jacob	Bruce	Jeff
	Khadir	Matt	Mark	Murali	Rod	Abdul	Phillip	Suleiman
	Abraham	Theo	Murat	Rajesh	Damien	Duong	Lachlan	Yassar
	Raja	Alex	Jay	Mike	Cathy	Haan	Gregory	Henry
	Michael	James	Muttaiah	Arjuna	Sasha	Dean	Nathan	Jarrod
						Fitrio		
Semester 2	Ali	Edward		Timothy	Claire		Bruce	Jeff
	Khadir	Matt		Murali	Rod		Phillip	Cathy
	Abraham	Luke		Mike	Damien		Lachlan	Murat
	Raja	Taylor		Theo	David		Alex	Henry
	Kumar	Brett		Lucas	Andrew		Jacob	Jarrod
	Khan	Leigh			Michael		Sanjay	Yassar
							Leon	

The students in the first year electrical engineering degree exhibited considerable diversity in educational background, age, country of origin, ethnic background, language background and work experience. Each team was categorised as homogeneous or heterogeneous based on the ethnicity, school experience, previous work experience, and age of its members.

Gender diversity was not extensively considered initially as there were only four female students out of the 79 students enrolled in the course. Three of the female students were in Team 5 in Semester 1. The other female student was in a team that is not mentioned in this dissertation. However, the issue of gender was considered when later analysis revealed that gender had a strong influence on the behaviour of some team members.

Fifty students consented to participate in this study and this included all members of nine of the 14 teams in Semester 1. Eight teams are discussed in this chapter to provide a general insight into the overall PBL setting in first year undergraduate electrical engineering degree programme. In Semester 2, due to attrition and some students repeating the PBL Subject 1, some teams were dissolved and the remaining members in those teams were asked by PBL supervisors to self-select other teams. Supervisors also allocated students to teams if they were unable to find a team.

As described in Chapter 4, students in this PBL setting solved three problems in Semester 1 and a project in Semester 2. The first problem that students solved in Semester 1 was an individual problem as well as a team building exercise. Students were asked to self-select their team members for the rest of the semester while they solved Problem 1 in the laboratory. By the end of Week 2 most students managed to select their team. Other students were allocated into teams by PBL supervisors.

A summary of the characteristics of three teams are presented in Table 6.2 below to illustrate the method of analysis. A summary of the characteristics of all the eight teams are presented in Appendix 11.

Table 6.2 Summary table of PBL team characteristics

	Membership	Group processes	Team leadership	Learning approaches	Approaches to PBL	Learning culture
Team 1	5 Students – Sem 1. 5 Students (including 2 new students) – Sem 2 Mixed ethnicity Local & International students Diverse school experience Same age group	Students formed groups within the team, lack of respect for other students, team work was constantly interrupted and students contributed to self-selected individual tasks. No co-ordination. No effective group processes	Leadership was seen a powerful role and students competed for authority. There was more than 1 student leading the team at a given time.	All students had surface motive and aimed at completing individual tasks. Used surface learning strategies and focussed towards passing the subject. Students rarely engaged in subject related conversations during team meetings.	Students solved individual tasks. Sometimes solutions of other teams were copied. Information was not shared, group discussion was not observed and tasks were completed on a superficial level. Students advised PBL was about improving writing skills. At times the teacher helped the team to problem solve.	Finishing culture
Team 4	5 Students(1 dropped out) – Sem 1 5 Students (2 new) – Sem 2. Mixed ethnicity Local students Diverse school and work experience Different age groups (1 mature a student)	Students rarely socialised. Dominant member of the team organised the team work and delegated tasks to other students. He influenced the passive behaviour of most students as he did not trust them to complete the tasks.	Leadership was not effective. Mature age student dominated the team functioning and automatically assumed leadership.	1 student was career motivated and took an achieving approach. 3 students had a surface motive. They did not seek to perceive the new knowledge that they were exposed to by the leader. Group discussion or team work was not evident. These students used a surface approach.	The mature age student influenced the passive behaviour of other students. He thoroughly but individually solved problems and exceeded the expectation of the teacher. 1 student assisted this student in laboratory work; another assisted in testing circuits that were already tested by him.	Performing Culture
Team 8	5 students in Sem 1 6 students in Sem 2 Multicultural Local & International students Diverse school and work experience Different age groups (1 mature age student)	Students socialised, were inclusive of each member. They took responsible roles and displayed positive team working behaviour. Students collaborated with each other and shared every task. They often met unsupervised and face-to-face to problem solve as a group. Students criticised, provided feedback and supported each other.	1 leader throughout the year. Outstanding leadership, team building, management and supportive qualities observed.	1 student was deeply motivated. Others were motivated to achieve high grades. The deeply motivated student became the leader of the group and influenced other team members to approach deep learning.	Students demonstrated outstanding communication, interpersonal, problem solving and time management skills. They consistently worked hard and produced more than one solution to each problem.	Collaborative learning culture

6.2.1 Teams that adopted a finishing culture

6.2.1.1 Team 1

In Semester 1 Ali, Khadir, Abraham, Raja, and Michael were members of Team 1. Ali and Khadir were two of the twelve students described in Chapter 5. Ali, Khadir and Abraham were local students of African origin. Raja was an international student from India and Michael had travelled interstate to Victoria to pursue his educational goals.

In Week 2, during the team selection exercise, Michael made some strong racial comments and expressed his beliefs about people of different ethnic background in a laboratory classroom filled with multicultural students. He tagged, labelled and generalised about persons of different ethnicity and earned the dislike of most of the students who were in the laboratory. Because of his racial prejudices, Michael was rejected by many teams. When his supervisor allocated him to this team, he was not willing to join them but was left with no other choice.

Ali and Khadir went to secondary school in Africa and in Australia. They were friends before joining this course. Abraham had recently migrated to Australia with his family. Because of his innocence of the "way of life" in Australia and its geography, he soon became the clown of the class. He often did not remember the names of roads and pronounced the names of suburbs differently to the local pronunciation. Abraham was made fun of by Ali and Khadir on many occasions but, they also remained very supportive to Abraham, socialised with him and informed him about things that he needed to know for his day-to-day life. Ali and Khadir lent Abraham a helping hand and let him do things at his own pace. They showed him around the campus, helped him access the library and also took him on a tour of the health and recreation centre. In the process, they started to build a small group within the team. Michael and Raja did not seem to understand why Abraham needed more time.

Michael was unsympathetic about Abraham's situation and demanded that he complete the tasks assigned to him quickly so that the team could submit their work on time. Raja pushed Abraham and tried to direct and regulate him and set deadlines every time when Abraham was given a responsibility. Abraham responded with a racial comment and asked for him to be more compassionate. The following is an excerpt from the field note taken as the team members finished up a supervised team meeting in Week 5.

> Ali: So are you going to come to the uni to do the testing?
>
> Abraham: Yeah man. I will. But [I] can't say what time I will be in. [I] will call you when I reach here.
>
> Raja: Great. Will you give us a result before Christmas?
>
> Abraham: Why do you go whack whack (also shows a hand gesture to represent opening and closing of mouth) all the time. You Indian boys always panic. (Team members laugh) Just take it easy man.

In the first semester Ali and Michael often engaged in verbal clashes about team leader. During unsupervised team meetings, such arguments sometimes developed into physical fights[5] between Ali, Michael and Raja. Ali nominated himself as the team leader and demanded that members listen to his commands. Michael on the other hand, always competed with Ali and fought for authority. It was apparent that the social behaviour of the team complicated their group processes. Clearly the members were struggling to identify their roles, responsibilities and learning needs. They worked individually and did not discuss or exchange any information related to their individual tasks.

Occasionally during supervised team meetings, Raja and Michael engaged in subject-related conversations with their supervisor. However, the other team members remained silent. Ali sometimes raised questions about the group processes which were misunderstood by the supervisor as questions about the portfolio. Khadir and Abraham remained passive and only answered questions that were directed to them.

In Week 5, the supervisor noticed that the team had not completed the circuit design for Problem 2 and reminded them about the deadline. Michael decided to take charge and constructed the circuit by himself. He refused to share the workload with Raja and Ali who were both present with him in the laboratory. This incident intensified the clash between and Ali and Michael and they both argued in the laboratory for more than half an hour about who would conduct the experiment. Later Ali left the scene

[5] Michael normally initiated the physical clash. As an example, Michael slapped on Ali's head with his palm during a verbal argument. This action soon became a chain and Ali, Michael and Raja exchanged slaps on each other's head.

having failed to convince Michael to share the learning resulting from the work done in the laboratory.

In an informal interview, Ali raised concerns about the behaviour of Michael towards him and suspected that his young age may have contributed to the immaturity he displayed. He also indicated his dislike for Michael's "bossy" attitude in the team and declared that he would not study with him in future semesters. Abraham mentioned that he did not care whether he passed or failed in the subject and that he was disappointed with the ongoing arguments between team members. He asked them to respect each other. However, his request was ignored by Ali and Michael, who dominated the team.

In the following week, Michael reported to his supervisor that he had completed all of the circuit design and construction by himself without any help from other members in the team. Ali reported to the supervisor that his offer of help was turned down and that Michael did not let him engage in any activity inside the laboratory. The supervisor demanded an explanation for their behaviour, warned that such behaviour is unacceptable and asked them to accommodate and share the tasks equally amongst themselves.

Soon after the progress presentation in Week 6, Michael and Raja left to meet with their families and returned to study only in Week 8. By then Problem 3 was delivered and Ali had taken control of the components that were provided to the team. However, Ali did not make any attempt to design a circuit or find out how to use those components appropriately. He searched the Internet along with Khadir and looked for shortcuts so that they do not have to engage in thinking about designing a circuit to solve Problem 3. They located some relevant information, but did not recognise its relevance or how to use it in problem-solving. They also did not discuss their findings with their supervisor and hence their supervisor assumed that the team was not working very well.

In Week 9, surprised by the fact that the team had made little or no progress in Problem 3, their supervisor decided to step in and offer help. Their supervisor spoon-fed the design to them and asked them to construct and test the circuit as per the instructions provided. They were also provided with reading material, which outlined the definition of the terms relevant to Problem 3. This reading material, which contained sample designs, was not provided to other teams. Once again, there was disagreement between Michael and Ali about who would construct the circuit in the laboratory. The supervisor then offered to construct and test the circuit for the team and asked the students to observe.

Surprisingly, all of the team members passed the requirement of PBL Subject 1 and enrolled for the PBL Subject 2 in Semester 2. Michael approached the members of Team 5 and expressed an interest in joining them. The members of Team 5 decided to accommodate Michael in their team as they had lost team members to other teams. Ali was happy that Michael had left their team.

In Semester 2, this team had a different supervisor. The team was also allocated two new team members Kumar and Khan who were international students from East Asia. Raja was excited to take Kumar and Khan under his wing. Ali, Khadir and Abraham agreed and were happy to include the new team members. Raja negotiated with Ali and put forward the idea that the team would not have a leader. He persuaded Ali to agree by suggesting that each member could take the leadership role on rotation and hence, would also have a chance to assume other roles such as "the chair" and "the scribe" for every supervised meeting. Ali instantly agreed to this idea without realising that Raja was becoming an implicit leader of the team.

Ali chaired the first meeting where they delegated tasks to individual members. At the end of that meeting, Kumar, Khan and Raja started to converse in their own native language. Abraham asked them to speak in a language that everyone understood, but Kumar and Raja laughed his request off. This behaviour continued frequently in the following weeks. Ali sometimes interrupted their conversation and asked them to repeat what they had just said in English. At times, Raja volunteered to explain, but Kumar or Khan seemed to ignore the presence of others in the team and mostly conversed in their native language.

From the beginning, most of the members started to disengage and have fun. After Week 4, Abraham and Kumar were absent from team meetings. Abraham said that he would rather play basketball than attend PBL meetings. He added that he understood basketball better than PBL. Ali, Khadir, Raja and Khan approached the problem individually at a surface level. They did not attempt to make sense of the concepts that they came across and used them without understanding its significance in their tasks. Khadir paired up with Ali at times and they both looked for shortcuts on the Internet. They searched for different traffic regulatory and control systems in Australia and around the world. Raja and Khan delegated themselves the tasks of surveying an intersection. They also volunteered to perform the programming for simulating the intersection.

Raja and Khan selected their tasks and left the rest of the team with little or no work. Other team members were left with choosing between the design and test of the control mechanism. When programming the simulation model, Raja and Khan made no attempts to include the rest of the team members. They did not discuss the program or share their learning with other team members. Other members appeared uninterested and made no attempts to learn. This contributed to the increasing passivity of most members of the team. Kumar offered to help Raja and Khan occasionally with some simple tasks. But he mostly joked and spent time socialising with them. He also invited his friend from another team and engaged in social conversations, often in his native language.

The team also struggled to meet the deadlines that were previously set. Raja possibly felt that the pressure and the workload were a little too much to manage and decided to play the PBL game by taking shortcuts. Raja persuaded Kumar to stand by his side and with Kumar's help he borrowed ideas from other teams as they discussed their progress with their supervisors by often peeping into their studios and listening to their conversation.

Raja discussed the ideas that he overheard from other teams during supervised team meetings with his supervisor and presented them as if they were his own. In Week 5, when other teams had already presented their first progress presentation, the members of Team 1 were still struggling to make sense of the problem. Concerned about the progress of the rest of the members of the team, the supervisor spent an increasing amount of time during most supervised team meetings to help the team organise their tasks and initiate the problem-solving process. The supervisor also gave them an extension of time of one week to present their progress.

By the end of the semester, most of the work was completed by Khan and Raja. Ali, Khadir and Abraham did not make any attempt to understand any of the tasks that were completed by Khan and Raja. Ali and Khadir only contributed to the literature review section of their team's technical report and Abraham made no contribution. As a result, only Raja and Khan learnt any software programming and designing digital electronic circuits. Ali and Khadir advised that they had not spent much time in preparing the portfolio and had drawn most of the written work from their previous semester's portfolio. Despite the fact that there was no collaboration or co-operation among team members, all members except Abraham passed. Raja obtained a Distinction, Ali and Khadir obtained a Credit and Kumar passed the PBL Subject 2.

In summary, the members in this team were of diverse ethnic and school experience backgrounds. They lacked harmony and respect for each other and displayed little or no co-ordination. Members competed for authority and at a given time more than one member acted as the leader of the team. They did not share responsible roles and therefore did not organise effective team work. Team members interrupted each other frequently during supervised and unsupervised team meetings. Dominant team members completed tasks individually that they self-selected and refused to share any information or the workload with other members. They displayed a lack of commitment and showed little or no interest in contributing to their own learning or the learning of other members in the team. Under these circumstances, individuals learnt to take shortcuts in the first semester as they approached learning at a surface level. They were willing to take a similar approach in the second semester as well to minimally pass the PBL subject. Their shared beliefs, attitudes, behaviours and actions indicated that the team was motivated only to finish the problem-solving process with minimal effort.

6.2.1.2 Team 2

The members of Team 2 in semester 1 were Edward, Matt, Theo, Alex and James. Edward, Matt and Theo were among the twelve students described in Chapter 5. Members of this team were of homogeneous ethnicity but with diverse educational experiences. Most of them were of similar age except for Theo, who was the oldest in this team.

Theo had previous higher education experience at an Australian university. Matt had a previous vocational qualification in a similar trade. He lived close to the campus at the student village as commuting to the campus and accessing the facilities after hours were easier that way. Edward was a school leaver. He did not have any particular interest in electrical engineering, but mentioned that he was prepared to see “how things worked” for him. He advised that travelling to the campus was a challenge for him.

Alex and James were also school-leavers. Alex mentioned that he worked part-time while studying at university. He was always quiet and exhibited a reserved personality. He did not socialise or converse with anybody in the team. James was also very silent and rarely socialised with others in the team. It was observed that James and Alex rushed out to the car park immediately after the lectures in the first half of the day and it appeared that they both had other engagements during most afternoons such as a part-time job. Therefore, their participation in PBL was limited from the beginning of the first semester. After attending the supervised meetings in Weeks 1 and 2 James dropped out of the course for unknown reasons just before the census date (31 March 2006).

In Week 2 of the course, Matt helped to get Edward’s robot to work properly. Soon, Matt and Edward became firm friends. During supervised team meetings, Matt displayed knowledge superior to that of his team members about electronic components and circuits, which attracted everyone’s attention. Matt asked questions of his supervisor about the problem as it was delivered. He demonstrated confidence and made his team members think that he possessed sound knowledge and skills relevant to the problems. But, it was clear from Matt’s questions and conversation that he made up ideas and seldom provided any evidence to substantiate his claims. Matt automatically became the leader of the team. Edward thought Matt was “intelligent” and so he paired up with Matt “to learn” and supported him in solving the problems.

Theo attended team meetings only occasionally and did not offer to help the team with anything. He also did not finish the tasks that were assigned to him by Matt. He refused to contribute and did not take any responsibility in the team while solving Problems 2 and 3. He enjoyed the role of a freeloader and interpreted autonomy as freedom to decide when to attend the meetings. He participated in the team meetings only when he thought it was necessary. His excuses normally were that he was busy with paid work or he wasn't feeling very well.

Theo normally socialised with Edward only to uncover any information that he might have missed while he was absent. He appeared to be very reserved and preferred not to communicate much with Matt or Alex. Theo once mentioned that Matt always spoke to him in the language of the subject and that often irritated him because he did not know as much as Matt did. He also mentioned that Matt's attitude made him feel like an "idiot" and that he did not like working with Matt.

Alex only responded to questions from his supervisor and sometimes spoke to Edward. Along with Edward, he shared an aversion to an academic staff member who taught them one of the lecture-based subjects. They both discussed and made fun of that staff member using a nickname that they jointly gave him. This incident attracted students from other teams who were interested in the gossip and fun. These members then became frequent visitors to the team. Matt and Edward started to socialise with them at the University bar during 'happy hours[6]'.

During the oral presentation for Problem 2, Matt and Edward addressed concerns about the accountability of individual students in their team. Matt advised that he and Edward worked very well together, and reported to his supervisor that the other two members were not willing to participate. His supervisor suggested that they both needed to find a solution by expressing their views to their team members explicitly. Matt expressed disappointment about the advice he received from his supervisor and thought that the supervisor did not help them to deal with the behaviours of the team members.

By the middle of the semester, both Alex and Theo had missed a few important supervised team meetings, including the meeting when their supervisor delivered and explained Problem 3. Matt and Edward, who were already struggling with the increasing workload, struggled to delegate tasks to Alex and Theo. Matt clearly indicated that he did not want to compromise his grades by spending time mentoring Alex and Theo. While Edward fully supported Matt's decision, Theo and Alex thought that Matt was not letting them have a chance to learn.

[6] During happy hour alcohol and food is sold on a subsidised price within the university campus.

Edward initially offered to help both Alex and Theo with their questions about the problem and the tasks that Matt decided for their team. But, when he struggled to meet Matt's deadlines, Edward started to ignore their questions and followed Matt's instructions. In this situation, Edward was also becoming non-cooperative and did not offer to help Theo and Alex, which led to their increasingly passive behaviour.

As Theo and Alex did not take any responsibility, Matt and Edward were left by themselves to solve Problem 3. Matt completed the design, construction and testing of the circuit for Problem 3 by himself. Edward indicated a lack of interest and worked only when directed by Matt. He offered Matt moral support by bringing him lunch and helping him with other things, for example bringing the equipment that Matt required for testing.

During some occasions, Edward was observed testing the circuit, but he waited for step by step instructions from Matt. By Week 8, Matt and Edward only wanted to complete the subject to obtain a pass. Tighter deadlines and unco-operative team behaviour challenged their focus. Both Matt and Edward met with each other unsupervised more than three times a week during Weeks 8, 9 and 10. Edward allowed Matt to perform the experiments in order to finish Problem 3. They did not talk to other members about their design, construction or the findings of their experiments.

It was apparent in Semester 1 that Matt attempted but failed in co-ordinating team work. He did not effectively perform in his leadership role and possibly assumed that leadership was about taking on the entire workload when team members become unco-operative. Matt also prepared for the final presentation in the end and allocated each team member a topic to present. He implicitly asked them to pretend that everyone had contributed to the task when he discovered that only teamwork was rewarded with a higher grade. The following is an excerpt of field notes taken during an unsupervised team meeting in Week 10.

> (Edward received a text message from the Alex. He passed his mobile phone to Matt and Theo and asked them how he should reply.)
>
> Edward: "Do I reply saying, it doesn't matter you don't have to come today. You have not been coming for the last one month anyway. No I don't want to be bitchy. I will just send him a reply saying that, don't forget the presentation on Thursday".

Matt: Ask him to prepare the notes that I sent him.

In spite of not contributing to the team and not offering to learn as part of a team, Theo and Alex managed a Pass in the PBL Subject 1. Edward stated that Alex plagiarised his portfolio and that he had made a formal complaint about it. Matt obtained a High Distinction after writing a good portfolio. Edward only managed to obtain a Credit as he ended up writing his portfolio by himself. Both Matt and Edward were upset about the grades that Theo and Alex obtained and questioned the reliability of the assessment system.

In Semester 2, Edward and Matt ejected Alex and Theo from their team. Matt said that he only wanted members who would contribute equally in his team. Matt had earlier met Luke (member of another team) and observed him conducting experiments. Impressed by Luke's work, Matt invited Luke to join their team in the second semester. Edward asked Taylor, Brett and Leigh to join their team. Matt said that he was happy and that he would not have to do all the work by himself anymore. He was sure that Luke would share the workload with him. Matt also held Leigh in high regard as he thought he was very sensible and quick-witted. But Matt was later disappointed when Leigh dropped out of the course for unknown reasons without notice in Week 4.

Taylor and Brett were regarded as clowns by the team. They often directed the team's conversation towards sex. They also indulged themselves in performing a sex-like act in front of the team but in the absence of their supervisor. During the first half of Semester 2, all the members of the team were happy and enthusiastic.

Matt organised the tasks for solving the traffic intersection problem. He delegated himself the task of simulating the intersection. Luke volunteered to take up the role of a scribe for every supervised team meeting. He organised an agenda template for their team's meetings and also offered to help Matt with programming for the simulation. Edward appeared to be anxious and complained that he was frustrated with the way PBL was administered. While Edward was already frustrated by his experience of PBL in the first semester, the half-page problem description provided to students in Semester 2 seemed to fuel it. He became increasingly passive and did not take up any tasks. Matt asked Edward to survey the intersection. Edward agreed to survey the intersection with Taylor and Brett, but instead spent time socialising and making comments about girls passing by on the road and returned with indistinct findings.

Unhappy about the way the survey was conducted, Matt demanded that they explain why they failed to follow simple instructions. This incident ignited an argument between Edward and Matt. Luke intervened and urged them to reach agreement. In an individual interview, Edward reported that he failed in the two lecture-based subjects in Semester 1 because PBL took all of his time and efforts. He mentioned that he enrolled in PBL Subject 2 only because it was compulsory and expressed a preference for individual learning through the lecture-based mode. He added that he never wanted to hear the letters "PBL" again because of the frustration it has already caused him.

Matt delegated the speech for the oral progress presentation to his team members and asked them to pretend that they had actually performed the tasks that they were allocated. He gave them information to read, suggested possible questions that the audience may ask and also provided them with the answer for those questions. When he saw that they were struggling to make sense of the concepts and realised that the oral presentation might become a flop, he came up with the idea of "PBL party". He quickly organised for the team to participate and dance semi-naked in the "PBL party" video clip, a parody of the YouTube hit Numa Numa[7] to demonstrate their team work.

Matt directed and videotaped the dance. The entire dance was choreographed to display sexual gestures and innuendo. He also thought that by showing that video, they only would have to present their actual work for a shorter duration and the audience, especially his supervisor may only remember the video in the end. He also believed that they could use the video as an evidence of the use of technology and innovation. The "PBL party" video clip was later uploaded on the University's online learning system (WebCT).

By this time, the members of this team had already become celebrities, shaped their identities among members of other teams and had defined their team's norms.

[7] Numa Numa is an internet phenomenon based on amateur videos, particularly Numa Numa dance by Gary Brolsma made for the song "Dragostea Din Tei" as performed by Romanian Pop band Ozone. Ever since this video became famous in 2006, there have been an increasing number of parodies hosted on Newgrounds, Google video, Youtube and elsewhere (Wikipedia, 2007).

Members of other PBL teams were impressed by this video and started a closed debate, which was accessible to all first year electrical engineering students on WebCT. This debate attracted the attention of members of other groups who soon started exchanging their views through email communication on WebCT with the members of this team.

Edward, who was already frustrated about the PBL process used the opportunity to make racist comments on WebCT about a member of the teaching staff. While most students intended to have fun, some of them used the opportunity to attack the University, its staff and their teaching methods. Some students from other PBL groups named the members of this team a bunch of “gay guys” and some others called them “weirdos”. One student, who was concerned about the comments, questioned the ethics of such discussion on WebCT, demanded an inquiry and asked supervisors to put a stop to the sexist and racist debate on WebCT. The communication was interrupted and deleted by a PBL supervisor at a later date when inappropriate content such as sexist references about members of this team and racist references about a teaching staff member were found.

By the middle of the semester, Taylor, Brett and Matt started to display passivity. They started to absent themselves from supervised and unsupervised team meetings or cracked jokes when they attended team meetings. Taylor and Brett offered to help constructing the digital control circuit that Matt and Luke designed, but then withdrew and left the construction task half-completed because they could not understand the circuit design. Edward did not participate and did not contribute towards any task in the project.

Matt did not complain about team member accountability in Semester 2 because he thought it would compromise his grade. As his intention was to achieve a high grade he completed the traffic intersection project with Luke’s help. Matt appeared to know what his supervisors looked for during team meetings. He explained his ideas and the ways in which he implemented the design to his supervisor during team meetings. Taylor and Brett acted as though they had contributed considerably and asked questions of Matt during supervised team meetings, but were never really looking for answers.

Towards the end of the semester it became apparent that Edward, Taylor and Brett had not contributed to the team's progress. Edward failed badly as he copied from his first semester's portfolio. His sluggishness was evident in his portfolio as he failed to amend the problem to reflect the work done in Semester 2. Taylor and Brett looked after each other and managed to pass the PBL Subject 2 after managing to submit a portfolio that they carefully edited.

In summary, the membership of this team was homogeneous in many ways. All members were local students and most of them had similar school experience. Most members in the team were socially focussed and were only motivated to minimally pass the PBL subjects. One member was motivated to achieve high grades and took on the role of a leader. Effective group processes were not identified in both semesters and most of the work was completed by two members who paired up with the intention of achieving high grades.

When team members started to become unco-operative and did not contribute to working on tasks, the leader of the team ended up taking on the entire work load and focussed on solving the problems in time for reporting. Learning was not shared between members and most members did not know the team's methods and solutions to problems. The team leader persistently identified ways to subvert the assessment system and asked team members to cover up and pretend that everyone shared the team's approaches to problem-solving. As a result all members passed PBL Subject 1 and all members except one passed the PBL Subject 2.

6.2.1.3 Team 3

Lucas, Mark, Murat, Jay and Muttaiah were the members of Team 3. The membership of this team was considered homogeneous as all members were Australian students of multicultural origin. Although their ethnic origin ranged from European through Middle Eastern to East Asian countries, they shared similar school experiences. The members of this team were all school-leavers.

Lucas was one of the individual students selected in Chapter 5 because of his archetypal behaviour. As reported there, Lucas had a very silent personality. His voice was seldom heard when he attended team meetings. In the initial weeks, he was very reserved and rarely spoke to anyone in the team, including their supervisor. In an informal interview, he mentioned that he aimed to achieve good marks. Murat added that he planned the same. It appeared that Murat was very structured and systematic in his approach. He showed the timetable that he made to meet the deadlines that he set for himself. He also appeared to monitor his progress in the PBL subject along with the requirements of different subjects he studied. On the other hand, Mark and Muttaiah were very talkative team members. They made their presence known by socialising, telling jokes and making fun of each other and their team members. Jay attended the PBL meetings until Week 3 and then absented himself without notice. He never returned and it was assumed that he dropped out of the course.

Most members except Lucas gelled well with each other from the beginning. As the weeks passed by, Lucas did not show any interest in socialising with the team. He displayed mixed emotions and it was unclear whether he was anxious or was unwilling to work in a team environment. Although, he attended all supervised team meetings, he disappeared soon after the meeting was over. He was clearly uncomfortable and did not communicate with his team members unless they explicitly asked him a question.

Murat started to realise the intensity of the course and its requirements only by Week 5, when the supervisor discussed their team's progress in Problem 2. While other teams had already started constructing and testing the amplifier circuit, the members in this team had not yet come up with a design. Mark and Muttaiah did not seem to give much attention to the requirements of the problem or the deadline for solving it. Murat assumed leadership of the group when he noticed that other members did not give much importance to time management. He quickly organised team-work, split the tasks and delegated them to each member of the team. He also asked them to take things more seriously if they intended to pass the subject.

Members of the team did not appear to appreciate that PBL demanded that students work together as a team. Soon after allocating the responsibility for the tasks, the team spilt for individual study and only met once a week for less than an hour for supervised team meetings. Lucas searched for information relevant to the problem. He occasionally discussed the requirements with Murat but concentrated only on finding a solution to his task.

During supervised meetings, students reported the progress of their individual tasks only when their supervisor asked. It was apparent that they never discussed ideas or shared information. Only Murat was aware of their allocated tasks, their progress or their findings. When it was time for the progress presentation Murat directed the team members to make presentation slides of their tasks. He then collated all of their individual work and asked Lucas to introduce each team member's task during the presentation. Throughout the oral presentation members reported the findings of their individual tasks.

In Week 7, the team assembled for a supervised team meeting to discuss Problem 3. As they waited for their supervisor to arrive, the team members socialised and exchanged their mid-semester break experience. As Lucas remained silent, Mark decided to make fun of him. Mark claimed that he found out that Lucas was 'gay'. Muttaiah joined with Mark and mentioned that he had doubts about Lucas earlier on. This incident, which started off as fun, ended up upsetting Lucas, who stated that he was not 'gay' and asked them to stop making up stories. He added that being quiet does not say anything about a person's sexual orientation and asked them to stop teasing him. In response to this, Mark and Muttaiah continued their taunting behaviour and continued making fun of Lucas.

Muttaiah and Mark started to display an increasing amount of interest in socialising rather than involving themselves in working with the team or solving problems. Muttaiah said that "solving problems and studying hard are bitch's jobs". He also mentioned that he believed boys were meant to have fun.

The team somehow managed to complete Problem 3 on time. But, Murat was not satisfied with the accountability of other team members and the team's progress. He complained about a member's accountability to his supervisor in a supervised team meeting in Week 8. In response to this concern, the supervisor asked the team members to become responsible and act like adults. The supervisor also asked the team members to start using WebCT to share information and warned them that their grades might be affected if they did not accumulate enough evidence for discussion within the team. In an informal interview, Murat mentioned that the team could have achieved more if everyone, including the supervisor, took more responsibility. He added that their supervisor was surprised to see that Problem 3 was completed and definitely knew that he had mainly contributed to the progress.

When the results arrived, Muttaiah failed PBL Subject 1, along with the other subjects taught in lecture-based mode. Murat obtained a Distinction in PBL Subject 1. Lucas and Mark managed a Pass. As the team was left only with three members, the supervisor asked them to find other teams that they wished to join or find members who wished to join their team. When Murat expressed his willingness to join other teams, the supervisor allocated him to Team 8, Lucas was allocated to Team 4 and Mark selected another PBL team and joined them in Semester 2.

To summarise, the membership of this team was homogeneous in many ways. The leader of the team split the problem into individual tasks and assigned them to team members. Two members who enjoyed socialising always diverted the team's focus to social conversations. Effective group processes were not developed and the team leader expressed concerns over the accountability of team members. The team's approaches to problem-solving were focussed on completing the problems with minimal effort. Both Problems 2 and 3 were completed at a surface level as the members did not discuss each others' tasks, validate their findings or substantiate their claims with evidence. In this situation, finishing became more important to the team than learning from the problem-solving experience.

6.2.1.4 Characteristics of finishing culture

From the narratives of PBL teams presented in this section, it can be noticed that students in Teams 1, 2 and 3 were extrinsically motivated and therefore engaged in learning as a team only to pass with minimal effort. The teams were either homogeneous or heterogeneous with respect to students' demographic characteristics. Most students in these teams assumed relatively passive roles and they were inclined towards finishing the problems or project by solving individual tasks. They did not tend to see a connection between the problem and the learning outcomes and appeared to believe that the expected outcome in PBL was to "solve" the problem.

Most students in these teams only attended supervised team meetings. Communication between team members was poor and they often interrupted each other during team meetings. There was little evidence of co-operation or collaboration between team members. The leadership role was contested and team leaders directed team members to work individually. Most students used a surface approach to learning. Information was rarely shared between team members. Most work was performed by one or two team members. The attitudes and behaviours of students in these teams indicated that they adopted a finishing culture with a focus on finishing each problem or project.

6.2.2 Teams that adopted a performing culture

6.2.2.1 Team 4

The members of this team in Semester 1 were Timothy, Murali, Rajesh, Mike, Arjuna and Walter. Walter dropped out of the course by census date (31 March 2006) leaving the team with five members after Week 4. Murali, Rajesh, Arjuna and Mike were local students of multicultural origin. They all were school-leavers. Timothy was one of the twelve students described in Chapter 5. He was a mature age student with previous work experience in engineering. Due to his prior knowledge, he almost immediately approached solving the problems on the same day they were delivered.

Timothy rarely socialised and seldom conversed with his team members in a context other than subject matter. Initially, Timothy displayed exclusive behaviour in group meetings. He preferred to communicate only with Mike, who was an Anglo-Australian student and sometimes asked for his suggestions. It appeared that Timothy may have had some kind of racial prejudice because he completely ignored the presence of Murali, Arjuna and Rajesh in the team and blocked all communication initiated by them.

Rajesh studied in an Australian education setting only from Grade 9. His language and communication skills were not very well developed and he used a lot of colloquialisms from his country of origin. He was made fun of by his team members for his language. Rajesh appeared to be unconcerned most of the time, but some of the time disengaged from the team temporarily and avoided any social conversations. Rajesh thought working closely with Timothy would be a remedy to his social problems and quickly became his assistant. Timothy diverted the team’s attention to the problem when ever the team tried to socialise and indirectly asked the team to focus on solving the problem. Timothy took control of the team and assigned himself the role of the team leader.

Murali and Arjuna were passive participants from the beginning of the semester. They did not seem to integrate with the team and showed no interest in identifying their learning needs. It appeared that they enjoyed their role as freeloaders. Both did not contribute to any tasks or to solving problems as a whole. While working on Problem 2, Rajesh did the things that Timothy asked him to do. Rajesh and Mike mainly contributed to research and obtained information relevant to every problem from various websites on the Internet. They also used books from the library and searched for various methods to set up experiments and perform testing. They then consulted with Timothy to identify the trustworthiness of the source of the information gathered and later summarised their findings.

However, Timothy used the circuit that he designed to conduct experiments and presented it to the supervisor as if it was the team's idea. He organised Mike and Rajesh to work with him to construct the circuit and to perform various tests. However, when Mike and Rajesh struggled to understand Timothy's ideas, he asked them to just finish the construction and he decided to carry out the tests by himself. Most of the time Rajesh stated that the test readings he recorded on paper for Timothy did not make any sense to him. He hoped that Timothy would clarify things in due course or, if not, that he would learn by some other means.

Timothy prepared the oral presentation slides and allocated topics to each member in the team. Their supervisor applauded their presentation saying that it was "very professional". Motivated to perform better than they had in Problem 2, the team set out to approach Problem 3 in depth. Timothy said to the team that they had not shared or brainstormed ideas for Problem 2 and he had identified that as a drawback. He then asked for the team to consider multiple ways of solving a problem and asked Rajesh and Mike to approach problem-solving individually. Timothy suggested to the team that they would then have more than one solution and that they could choose the best solution.

It appeared that Timothy was playing a game in order to escape from mentoring Mike and Rajesh. Unaware of his ideas, Mike and Rajesh started to investigate Problem 3 individually. Timothy used the opportunity to solve and thereby learn individually. Towards the end of the semester, Timothy presented his design as the team's design once again, but this time neither Mike nor Rajesh knew anything about the solution.

Frustrated with his learning experience in PBL, Arjuna dropped out of the course. Rajesh transferred to another course. Murali managed to pass the PBL Subject 1 by writing an impressive portfolio and remained in the same team for Semester 2. Timothy managed to obtain a Distinction in the PBL Subject 1. However, he believed that he should have obtained a High Distinction for his efforts.

In Semester 2, two other members, Theo from Team 2 and Lucas from Team 3, joined this team. Lucas displayed behaviour similar to that of Semester 1, in that he was very silent and did not engage in any conversations with team members. He walked out of the studio soon after the supervised team meeting finished and was never present for unsupervised team meetings. The contributions that Lucas made to the team included information searches on different traffic management systems on the Internet and preparing PowerPoint slides for the progress presentation and the final oral presentation.

After being "ditched" by his previous team mates, Theo was allocated to this team by one of the PBL supervisors. He appeared to take things more seriously than he did in the previous semester and participated in team meetings, both supervised and unsupervised. However, he did not attempt to make any significant contribution to the team. Having spent his time happily as a freeloader in Semester 1, Theo had a similar tendency in the second semester too. He knew how to present himself to look as if he was actually contributing. Apart from contributing occasional ideas in the traffic controller project, Theo did not pick any tasks. He played a supporting role to Timothy while he designed the digital circuit in the later half of the semester.

Timothy assigned himself all the major design, experimentation and testing tasks for the project and only allocated other team members minor tasks that were consistent with his approach to a solution. He presented his ideas to the supervisor every week during the team meetings and assumed that his team members would follow. He shared his ideas only when either Mike or their supervisor asked for clarification. He did not bother to explain his thoughts to his team members and allocated them bits and pieces of the tasks to keep them quiet. As an example, during Week 2 in Semester 2, Timothy asked Mike to conduct the survey and report his findings in a tabular form to enable him to do coding for the simulation. Not sure of what Timothy expected Mike spent the whole week in making a drawing of the location of the intersection.

In Week 7, Timothy allocated the task of reducing Boolean expressions to Murali to assist the digital design component of the problem. As he did not trust Murali's competence, he worked on the same task simultaneously and without Murali's knowledge. In the end, when Murali did not complete the task that was allocated to him to Timothy's satisfaction, Timothy persuaded the team to use his own design. Thus, the majority of the tasks including programming the simulation of the intersection, designing the digital control circuit and testing the circuit were completed by Timothy.

Timothy expressed frustration about having to wait for other team members with little confidence that their contributions would materialise. Timothy believed that PBL was a "waste of time" mainly because he was "sick of the idea of having to teach a bunch of kids, who have no idea about how things worked". He also expressed a preference for learning individually and thought that he could have completed the problem the same day it was delivered if he did not have to share the workload. He claimed that he had to do all the work by himself for the same reason and also mentioned that his team members "simply did not have the capacity".

However, he was good at creating an impression for his supervisor that all team members were equally contributing to the team's process. Hence all the team members managed to pass the PBL Subject 2. Timothy managed to obtain a High Distinction for his efforts this time. When asked to comment on his result, he explained that he did not have enough time to compose a new portfolio from scratch and had used work from his previous semester's portfolio. He also expressed confusion about the assessment system and mentioned that he could not understand why a similar portfolio only yielded him a Distinction in Semester 1.

In summary, the membership of this team was heterogeneous as members of this team had diverse school and work experience. The students in the team rarely socialised. They met regularly for both supervised and unsupervised meetings every week during the semester. The mature age student, Timothy, was highly motivated to achieve a high grade to enhancing his career opportunities. As he was focussed on the product (grade), he tried to maximise the chances of obtaining high marks and therefore he ended up completing all the problems individually at a high level.

It is likely that Timothy's work experience may have influenced his approaches to problem-solving. While he persuaded his team members to follow his ideas, he did not explain his findings to his team members. So it was apparent that he lacked team-work skills. It is likely that, because of his actions, some members slowly tended to lose motivated and become more passive. It is also likely that they believed letting Timothy do what he wanted to do would lead the team to outstanding results with minimal efforts. It is also possible that these members never challenged his ideas as they perceived his knowledge level and experience as superior to theirs. As they received good grades in the first semester, they followed a similar approach in the second semester. The strategies followed by the members of this team in both semesters indicated that they were inclined to achieve high grades. Under Timothy's leadership, the members of this team were able to deceive their supervisor into believing that they had worked well as a team.

6.2.2.2 Team 5

Team 5 consisted of five members: Claire, Rod, Damien, Cathy and Sasha. Damien, Sasha and Cathy were school-leavers. The members of this group were local students of multicultural ethnicity. Claire and Rod were mature age students. Therefore, the membership of this team was considered as heterogeneous. All the members were enthusiastic, energetic and willing to be part of the team at the beginning of Semester 1.

Claire was one of the randomly selected students described in Chapter 5. As reported there, she had a variety of educational qualifications and previous work experience in training and management. She was very outgoing, offered to help team members and volunteered to lead the team. Her writing skills were also well-developed. Claire was also self-motivated and self-directed.

Rod had a related trade qualification and several years experience in the industry. He had decided to continue studying to earn a higher salary and better positions. He displayed a reserved personality. He mostly communicated with Claire and did not initiate many conversations with other team members. He mentioned that he disliked the idea of learning in a group because the environment that was provided did not support flexible learning and the team members do not get to share and discuss ideas.

Rod expressed concerns about issues such as access to the learning spaces, the timeline to complete each problem as a team and the approachability of the staff members involved. He added that he struggled to cope as he also worked full-time to support his family.

Cathy studied electronics at high school as an elective only because other electives like music and arts were already full but felt that she had made a good decision then because it helped her choose her career. Sasha and Damien had joined tertiary education to get better jobs and electrical engineering was their first preference course. Damien said he would have joined commerce otherwise. Of all the members in the team, Damien displayed expert research skills. He quickly located and evaluated information that he found on the Internet and discussed it with Claire.

For each problem in the course, Claire motivated her team members to work on tasks that were of interest to them. After the team brainstormed all the tasks, she asked each member of the team to select a preferred task before she picked her own. She played the role of a mentor to Cathy, who had trouble organising references for her research. She also occasionally helped Sasha in selecting her tasks. Before the end of every meeting she explicitly reminded team members of the date and time of the next meeting and reconfirmed the tasks of each team member. Throughout the year, Claire's management expertise was demonstrated in her handling of group tasks and team members. She led the work of her team, composed team reports for Problems 1, 2 and 3 and managed tasks throughout.

Micro-managing the team members during both Semesters 1 and 2 became Claire's primary task. Yet she claimed to dislike this role and wanted someone else to take the lead. Using her excellent communication skills, Claire persuaded Rod to take the leadership role towards the end of Semester 1. She then worked alongside Rod to learn the technical knowledge from him that she lacked. Claire possessed clear self-awareness, willingness to learn and also appreciated the contributions of other team members.

Rod on the other hand volunteered to contribute to the design and construction of solutions to Problems 2 and 3 in Semester 1, partly because he believed that other team members did not have the capability to see the task completed. Rod persuaded his team members to let him handle circuit design and testing. Most of the time Rod solved each problem in the same week it was delivered to the team. However, he took more time to document the solution and sometimes depended on Claire to edit his written work.

During team meetings, Damien showed some interest in problem solving. He offered to help Rod in the laboratory, but Rod turned down the offer because it was easier for him to work at home than to work at the University laboratory. Damien’s role was thus limited to testing the circuit which Rod had already built and tested. Claire was nominated to compile the written work as the team believed that her written skills were superior to those of any other member of the team. Sasha and Cathy played supporting roles in searching for resources and contributing to the final technical report compiled by Claire, which was a mosaic of individual contributions.

Damien, Cathy and Sasha played increasingly passive roles as all of the problems in Semester 1 were essentially solved by Rod. As the team worked on solving Problem 2 and Problem 3 during Weeks 5, 6 and 7 it was apparent that they were heavily reliant on Rod’s ideas. Claire organised for Rod to solve the problem as she had confidence in Rod’s ability. Claire described Rod as the “rock of the team”. She stated that Rod deserved all the credit for successfully completing the projects and that she depended on Rod to complete them.

This dependence on Rod’s technical expertise was highlighted towards the end of Semester 1, when he was frequently absent. Without his contribution, the team struggled to submit the results of Problem 3 on time. Claire and Damien finished most of the tasks, pulling every piece of work together with relevant research material to support their solution, but in a superficial manner. Claire also helped some of her team members in editing their portfolios. Claire knew that better learning resulted if there was effective team discussion and understanding other team members’ tasks but she was willing to forgo this when time was tight. In this situation, for all team members, finishing became more important than learning.

Claire observed that the grade she obtained in Semester 1 reflected her contribution and workload. However, she felt that it wasn't fair that Rod obtained a grade lower than hers although he had contributed much more than any other team member in problem solving. She also mentioned that she could not understand why Cathy obtained a Distinction despite her unsatisfactory contribution.

In Semester 2, Sasha and Cathy decided to join friends in other teams. David, Andrew and Michael then joined Team 5. Michael was the youngest member of the team. Andrew was silent by nature and was a friend of David. The team also had a different supervisor in Semester 2. Claire quickly got into the business of organising the team and assigning tasks to the team members. She appointed herself the leader of the team and briskly dispatched different roles to team members. All members took turns in taking the roles of scribe and chair under her leadership. However, much of the work was only completed at a surface level as the team only met during scheduled supervised meetings. This was possibly because the PBL learning spaces were not available to students until Week 9.

After taking responsibility for circuit design and construction during Week 3 in Semester 2, Rod started to absent himself from supervised team meetings. Rod's absence had significant effects. Tight deadlines and spectacularly misguided hypotheses brought arguments and disagreement between Claire and David. David always questioned and challenged every team members' ideas and refused to accept decisions made as a team. David also refused to work with Michael and mentioned that Michael was racist and rude. He explained his perception by generalising that it was natural for people from Sydney to behave in that manner. However, other members of the team thought that David did not give Michael a fair chance as he did not trust Michael's decision-making due to his age.

David sought help from a family member who was working in a related field and frequently changed the ideas the team had agreed upon. He started to work individually but decided to keep Andrew by his side. He also requested components to build a model without advising Claire, who was co-ordinating placing an order for the parts for their design. When Claire found out from her supervisor that an order for the components had already been placed by a member of her team, she called a meeting and asked why the group was not informed. During that unsupervised meeting, David stated that he did not like Claire leading the team and told her that he should take over because she was a female.

Claire found David's comments insulting and sexist and she responded in a couple of emails by offering to just sit back. However, she promised to complete the tasks that she had assigned herself. After many telephone conversations from concerned team members and an apology from David, she started again to actively participate in meetings. In fact, her contribution was very much appreciated by the majority of her team members in the peer evaluations they included in their portfolios. When the results arrived, Claire was surprised that a similar portfolio resulted in a lower grade in Semester 2.

Towards the end of Semester 2, Claire became more frustrated with her PBL experience. She expressed concern that PBL was the only learning environment that she had encountered where the projects seemed to be designed to create a feeling of incompetence and failure in the students before they even commenced. She demanded a fundamental review of PBL's implementation and stated that the level of disorganisation and thoughtlessness in its structure was unacceptable. Claire complained about lack of supervision and support to overcome difficulties with group processes. She also demanded consistency between the expected outcomes outlined in the subject documentation and the directions provided by supervisors during supervised team meetings. Her claim indicated this team did not understand the expectations of the PBL supervisors.

To summarise, the membership of this team was considered heterogeneous as two students were of mature age and the rest were school-leavers. Most of the members were initially highly motivated and used deep approaches to learning. Claire organised group processes and delegated tasks to team members at the beginning in both semesters. However, Rod's perceptions of PBL influenced the team's learning behaviour as weeks passed by in Semester 1. He aimed at the final product (arriving at a solution to each problem, team technical reports and portfolio) and persuaded Claire and the rest of the team to use the strategies that maximised their chances of achieving high grades. This attributed to the passive behaviour of other members in the team and some of them contributed to PBL processes only when directed.

The workload was shared unequally among team members and the team overly relied on Rod's expertise even in the second semester. When Rod started to disengage and dropped out without notice, the team members became anxious, took shortcuts and used surface approaches to learning. The social makeup of the team disintegrated when the leadership role was contested. Gender-related issues affected the dynamics of the team. One member exhibited sexual prejudice against female leadership and engaged in individual activities although he had earlier agreed upon a shared strategy with the team. This member competed for social status or power in the team and exhibited little or no respect for members of the team who challenged his actions.

The approaches and actions of members in this team indicate that they were initially interested in achieving high grades. But, when some members decided not to co-operate, finishing became more important than achieving high grades in the second semester. All members, except the student who dropped out, passed both PBL Subjects. In fact, some of them achieved good grades on the basis of their individual written work in the portfolio. But it is uncertain whether the learning was effective as the team members did not attempt to share the findings of individual tasks. The team reports were compiled by one member, which was a mosaic of individual contributions.

6.2.2.3 Team 6

The members of Team 6 in semester 1 were Jacob, Abdul, Duong, Haan, Dean and Fitrio. All students except Jacob were school-leavers. Abdul was an international student of Middle Eastern origin. The rest were local students of Asian origin. Jacob was one of the students described in Chapter 5. He was a mature age student and worked full-time at his parents' restaurant. The membership of this team was considered heterogeneous.

Duong was the youngest member of the team. He displayed playful behaviour and was the clown of the team. Haan was a silent but studious member of the team. He was always prepared for supervised team meetings and answered most questions that the supervisor asked. As Abdul missed the PBL sessions during Weeks 1 and 2 to attend to the needs of his family, he was allocated to this team. Dean and Fitrio were also allocated into this team as they joined the course around the census date (31 March 2006).

During Week 3, Jacob asked for alternative supervised meeting times as he worked full-time. However, his request was turned down by the supervisor. When Problem 2 was delivered in Week 3, the supervisor asked the members to share and discuss ideas as a team. The supervisor also asked them to spend as much time as possible together in order to form a better understanding of each other's work and explained that those were the basic requirements of PBL. Abdul and Haan treated this message seriously and started to structure the group processes accordingly. They both soon assumed a shared leadership role.

Abdul asked the members to brainstorm ideas and identify tasks. He also asked the team members to initiate conversation if they were unsure of anything. Haan and Abdul organised their ideas and structured their approaches to solve each problem. They made timetables that corresponded well with the deadlines set by their supervisor. Although Duong was playful, he appeared to carefully analyse what was required of him by the team and promised to complete the tasks allocated to him on time. Jacob agreed too, but he was frequently absent for both supervised and unsupervised meetings after Week 4.

As Haan and Abdul lost confidence in Jacob, they quickly completed their tasks and also started to work together to complete the tasks that were allocated to Jacob. Jacob did not attend the progress presentation and the team assumed that he had not completed the task that was given to him. At this point, Haan and Abdul decided to use their combined solution to Jacob's task for the team's technical report.

Soon after the oral presentation was over, the team was observed working together in finalising the draft of their team's technical report due for submission. Abdul was also observed mentoring Duong when he helped him with word processing. Haan encouraged the team members to keep working towards the deadline by offering to buy lunch for the team every time they completed a task ahead of time.

Dean and Fitrio were allocated to this team just before the mid-semester break. The team quickly integrated the new members. But because it was Week 6 by the time

Dean and Fitrio joined the course, they struggled to understand PBL. Haan and Abdul made sure that Dean and Fitrio were up-to-date with all information. While they were involved in solving Problem 3, they explained where the team was up to and showed them their past experiments at the laboratory whenever they had extra time.

Abdul normally asked questions of Dean and Fitrio to initiate conversation and help them clearly understand the experiments. His questions also helped Duong to clarify doubts that he normally kept to himself. Under Haan's and Abdul's shared leadership, most members in the team collaborated very well in Semester 1. Everyone except Jacob made significant contributions to the problems and thereby to the progress of the team.

They searched for information on the Internet, used text books from the library and constantly validated their findings by discussing their progress everyday during unsupervised team meetings. They critiqued their findings by questioning their understanding of concepts and by performing experiments. Although most experiments they conducted were based on trial and error methods, the detail of their analysis indicated that they were focussed towards maximising their learning.

Haan mentioned that when a face-to-face meeting could not be organised, team members used WebCT to communicate. They shared subject-related material that they researched by email and also passed comments, critiqued findings and shared their views during weekends when they could not meet. Towards the end of Semester 1, as Jacob was unco-operative, the team discussed ejecting him from the team for Semester 2. When he discovered the team's decision, Jacob approached his supervisor and requested that he be placed in another team.

To summarise, the membership of this team was heterogeneous. Team members had diverse school experiences. Most members interacted well and organised their group processes. The team members identified their roles early during the semester and shared responsibilities to complete the tasks thoroughly. Most members were intrinsically motivated and were committed to their tasks. The shared learning strategies used by the members of this team indicate that they approached learning collaboratively. They also showed a commitment to their team's overall progress.

Two members shared the leadership role. They were very inclusive of the new members who joined the team just before the mid-semester break. Mentoring behaviour was observed in the team when some members had difficulty in understanding certain concepts. A leader also provided moral support to other members and motivated them to complete their individual tasks on time. Team members shared their ideas and discussed their findings regularly both face-to-face and on the Internet.

Members of Team 6, except Jacob, were not formally observed in Semester 2, as the scheduled team meeting of this team coincided with the scheduled team meeting of another team that was followed in both semesters. A few members were informally interviewed in Semester 2 but, that data were not sufficient to describe this team's activities in the second semester.

6.2.2.4 Team 7

Bruce, Phillip, Lachlan, Gregory and Nathan were the members of Team 7. Bruce and Phillip were two of the randomly selected students described in Chapter 5. As reported there, they were in the second year of the robotic engineering degree and enrolled in PBL Subject 1 as it was one of the core subjects that they had to study in order to complete the requirements of their degree. Lachlan and Gregory were also in the second year of the robotic engineering degree. All members were local students of Anglo-Australian origin. The membership of this team was considered homogeneous as students had similar origins and experiences.

Bruce explained that all members knew each other very well and added that he was a friend of Phillip, Lachlan and Gregory. Nathan knew Gregory from high school and therefore he invited Gregory to join their team. They all planned to work as a team as they believed that their knowledge level was more or less similar but superior to the other students who were in the first year of the electrical engineering degree course.

In Week 3, when Problem 2 was delivered to this team, their supervisor explained that one of them was expected to prepare an agenda, chair the meeting and take the minutes of the meeting and that they should work together as a team in solving each problem from then on. The students were also asked to nominate one member to lead the team through the PBL process for each problem. The very same day, Bruce made an agenda template and showed it to his team members and recommended using it for the rest of the semester. Impressed by his initiative, the team members asked Bruce to lead the team for that problem.

Bruce suggested the team should have an unsupervised meeting every week on a Monday as their supervised meetings were always scheduled in the later half of the week. Apart from this one extra meeting a week, he also suggested that the team should meet at a restaurant for lunch just before the actual scheduled meeting to brainstorm ideas, record the questions that they had in mind and be prepared in advance for their scheduled team meeting. Bruce also made a draft plan of tasks along with deadlines so that all tasks were completed before the deadline indicated by their supervisor. He then discussed that plan with his team members and supervisor to study its feasibility and then delegated tasks equally among the members of the team.

Phillip was assigned the task of a literature search and finding other relevant information to solve the problem such as laboratory manuals and user guides. Gregory and Nathan were assigned the task of circuit design. Bruce ordered the components and helped Lachlan with the circuit connection and testing. During each stage of the problem solving process, Bruce made sure the team discussed their ideas and mentored each other if anyone was unsure of any concept. The members of the team solved the problem by experimenting with new designs with the help of oscilloscopes, multimeters and other electrical and electronic testing and measuring equipment at the laboratory. They identified their mistakes and constantly worked to identify different methods to improve the design they explored. The members of the team spent more time in the laboratory than at the PBL studios and met almost every day to perform experiments.

Phillip expressed difficulty with his communication skills. He was mostly silent and did not discuss his findings much with his team members during supervised or unsupervised team meetings. Bruce and Lachlan identified his difficulty and asked him to summarise his research and send it to the team as an attachment by email. Phillip liked this idea and used WebCT to communicate with his team mates. The team finished solving Problem 2 well in advance when compared to other PBL teams. They used the excess time to jointly plan and rehearse for the oral presentation and prepared the team’s technical report for Problem 2.

While solving Problem 3, the team members switched roles. Bruce and Lachlan searched for literature to support their learning. Phillip worked on improvements to the design suggested by Gregory and Nathan. Gregory and Nathan also jointly assumed leadership roles for Problem 3. Nathan and Gregory exhibited a very strong understanding of circuit theory and helped other team members understand the circuits they suggested as the design for solving Problem 3. Phillip suggested an alternative approach to solving Problem 3. He brainstormed his ideas with the team members. Nathan and Gregory argued against and Bruce argued for Phillip. In the end, Phillip discovered that his idea may not work as well as the team's initial idea suggested by both Gregory and Nathan. Phillip reported that he benefited from discussions with Gregory and Nathan as they also helped him understand some of the concepts relevant to the lecture-based subjects.

Bruce's time management skill was well appreciated by all of the team members. They also added that, without Bruce, they wouldn't have known when to put a full stop to their inquiry. Bruce helped organise the team technical report and the oral presentation for Problem 3 in addition to his contribution to the theoretical knowledge base of the team. Bruce was particularly glad of the opportunity to edit the team's final technical report as he was able to view each team member's contribution from their point of view. While Bruce critiqued some of his team member's ideas and provided feedback to improve their written work, he also mentioned that he greatly benefited from editing as it improved his language skills.

In Semester 2, Gregory took leave of absence to attend to his family's needs. Nathan decided not to enrol in PBL Subject 2. Thus the team was left with only Bruce, Phillip and Lachlan in Week 1. The team also had a different supervisor in Semester 2. As the team had fewer members, the supervisor decided to place new members into the team. Although Bruce did not completely oppose the idea of new members in the team, he felt that the team would be able to manage the problem with the existing members. Dismissing further debate on this issue, the supervisor supplemented the team with new members. Alex (ex-member of Team 2), Sanjay and Leon were allocated to this team in the beginning of Week 3. Jacob, who was absent for the first three weeks and excluded by his previous team (Team 6) was also allocated this team in Week 4 of Semester 2.

Sanjay was an international student who worked part-time to meet his living expenses. During most team meetings, Sanjay appeared tired. He explained in an informal interview that he mostly worked during nights and it was hard to concentrate soon after finishing work. Leon was an Australian student. He was allocated to this team by the supervisor as some members of his previous team had failed and repeated Semester 1 subjects and other members joined different PBL teams. Leon was not very happy and mentioned that he felt “lost” in his new team. However, he mentioned that he was trying his best to adjust.

Bruce and Lachlan volunteered to organise the group processes for Semester 2. Bruce asked for the team members to nominate a day so that the team could meet unsupervised once a week, every week. The new members of the team expressed difficulties in attending the unsupervised team meetings. Jacob mentioned that there was no need for an extra meeting, if all members responsibly completed their tasks on time. Bruce then explained the additional team meeting would enable them to discuss problems with their tasks and would provide them with an opportunity to discuss the solution as a team. Unconvinced by Bruce’s explanation, all the new team members stated that they either studied a different subject or repeated some subjects from the previous semester and hence could not attend extra meetings.

When the team could not arrive at an agreed time for the meeting, Lachlan took over the lead and announced that the team will meet unsupervised on a Tuesday at 4.30 pm after all the classes were over. He also added that his decision was final and asked the members to try their best to be present. Soon after that meeting, when all the new team members left the PBL studio, Bruce said to Phillip and Lachlan that they would have been better off without the new members as they refused to co-operate.

During Week 4 and Week 5, Leon was absent for the supervised team meetings. Sanjay was absent for the supervised team meeting in Week 4 and Jacob was absent for the meeting in Week 5. As the new members of the team were frequently absent, Bruce decided to share the problem solving with Lachlan and Phillip. He delegated Phillip the task of the traffic survey while he worked with Lachlan on programming the simulation of the intersection. Phillip gathered the data for the timing of the traffic lights and worked on designing the timing and control unit of the traffic lights for their improved traffic management version for the intersection.

Jacob contributed minimally to debugging the software program written by Bruce and Lachlan. Leon, Alex and Sanjay gathered the literature around traffic management systems. In Week 5, when the team presented their progress presentation to their supervisor, it was clear that the members of the team had not collaborated. They presented their ideas and solutions to the individual tasks that they worked on. After their presentation, the team members were informed by their supervisor that their team will be split into two teams as the team size was large.

Thus Bruce, Phillip, Jacob and Alex remained in Team 7. Leon, Sanjay and Lachlan were asked to form a new team. Bruce and Phillip felt that the decision to split the team was unfair but continued to work hard. Bruce completed the simulation of the intersection and worked on improving the software program to include additional features. Phillip continued to design the timing and control circuit. Alex made a cardboard model of the intersection and helped Phillip in constructing the circuit.

Jacob was frequently absent for both supervised and unsupervised team meetings. He did not contribute anything and remained passive. When concerned team members called, he mentioned that he was busy with work commitments and hence could not attend. He promised to get closer to the team as soon as he sorted out his commitments. Bruce advised that Jacob stopped answering calls in Week 8 and assumed that he had dropped out of the course. The team also faced another blow when Alex advised in Week 9 that he had decided to drop out of the course for family reasons.

Thus, Bruce and Phillip were left by themselves to complete the entire problem solving process. Bruce encouraged Phillip every time he expressed frustration. He also helped Phillip in testing the control circuit. Bruce and Phillip also worked together to compose the technical report for the traffic intersection problem and completed the problem solving process on time. The supervisor commented that their time management and problem solving skills were remarkable despite facing a lot of obstacles.

In summary, the members of this team were of homogeneous ethnicity and had similar school experiences in the first semester. This may have enabled them to understand each other well and decide on effective group processes. They demonstrated outstanding time management skills and problem solving skills. All members were deeply motivated and approached learning at a deeper level. They delegated tasks equally and shared new knowledge and information effectively. Members also alternated roles so that each member got an opportunity to learn about organising teamwork and leading the team and thereby contributed to each other's learning through PBL.

The success of this team was short lived when their supervisor decided to introduce new members to this group. The team members from the previous semester could not cope in the new situation as the new members were not as highly motivated as they were. In fact, the new members aimed to complete the problem by engaging in minor tasks and taking shortcuts. The supervisor then decided to split the team into two.

Thus, this team was left with two members (Bruce and Phillip) from the first semester and a new member (Jacob from Team 6). Jacob was frequently absent from team meetings and generally refused to participate. At one stage he announced that he was dropping out of the course for family reasons. The strategies used by both Bruce and Phillip in the way they shared the work load to achieve the outcomes for Semester 2 indicates that they approached PBL collaboratively and used a deep approach to learning.

6.2.2.5 Characteristics of performing culture

From the narratives of Teams 4, 5, 6 and 7 presented above, it can be noticed that Teams 4, 5, and 6 were similar to Teams 1, 2 and 3 in that they focussed on finishing the problems. But, in addition, the focus for some students was on achieving high grades. They therefore discussed ideas, shared workloads and co-operated well to achieve this. However, attendance in unsupervised team meetings varied.

Students in Teams 6 valued team-work and worked inclusively in their team. Some students in Team 6 mentored their fellow team members who struggled to complete their individual tasks. Contrary to this, students in Teams 4 and 5, who were concerned with their own individual achievement encouraged passivity in other team members. These students either did not value the capability of other team members or did not want their decision-making to be compromised by participating in group processes.

Dominant team members who took the leadership role in these Teams 4 and 5 allocated tasks to members and directed them to work individually. Although the students in these teams shared their tasks, division of labour was often unequal. It is possible that their motivation to achieve high grades by completing tasks thoroughly often prevented them from sharing their findings and hence the learning experience of their teams. Students in teams 4, 5, and 6 presented a mosaic of individual contributions as evidence for team work. The attitudes and behaviours of students in these teams indicated that they adopted a performing culture, in the sense that the focus was on academic performance as indicated by grades.

During Semester 1, Team 7 was different to teams 4 through 6. Students in this team held positive relationships and mutually respected each other. They also discussed and shared ideas, findings and solutions to their individual tasks, thus making sure that everyone in the team understood the problem solutions. Students alternated team roles so that everyone in the team had their chance to be a team worker, a resource investigator and a leader.

The attitudes and behaviours of students in this team indicated that they adopted a collaborative learning culture in Semester 1. However, these practices were not maintained in Semester 2 because of changes in the membership of the team. Original team members who were previously disposed to collaborative learning found themselves amongst surface learners. Hence the team adopted a performing culture.

6.2.3 Team that adopted a collaborative learning culture

6.2.3.1 Team 8

There were five members in Team 8 in Semester 1: Henry, Jarrod, Yasar, Suleiman and Jeff. Yasar and Suleiman were international students. Jeff, Henry and Jarrod were local students of multiple ethnic origins. Jeff was one of the twelve students described in Chapter 5. Henry and Jeff were school-leavers; Jarrod was a mature age student who studied part-time. The membership of the team was considered heterogeneous.

Yasar had great difficulty in communicating with his team members because of his low proficiency in the English language. To improve his communication skills, Yasar attended an English Language Intensive Course for Overseas Students (ELICOS).

Henry preferred studying individually rather than in a team environment because of his work commitments. He worked part-time to fund his living expenses while studying. However, he took part in most of the team meetings and contributed to the team’s progress. Jeff mentioned that he did not work while he studied as his parents had offered to support him.

Jeff was chosen to lead the team in a vote. Jeff mentioned that he perceived, from what his supervisor advised earlier in the semester, that his team’s success is his success and a pathway to obtaining a high grade in the PBL unit was therefore to make a successful team. Consciously or unconsciously, Jeff ensured that information was shared and processed by everyone in the team. Jarrod mainly contributed to the team by organising team-work and research. He brought in a lot of research material, which was discussed by team members during every supervised team meeting. The team also met unsupervised once every week. Jeff became a firm friend of Jarrod. Jarrod and Henry supported Jeff, which made him even more comfortable allocating tasks and ensuring that they were completed successfully. Jarrod was considered a valuable member in this team because of his technical, time keeping, research and documenting skills. Every member in the team made use of Jarrod’s involvement as much as possible.

In Semester 1, Jeff normally chose his tasks and made sure he completed all of them well in advance. He also worked on finding alternative methods to solve a problem and came up with more than one solution to every task that he handled. Interestingly, his team’s solutions were not considered by other teams and sometimes surprised supervisors, who praised the team for being innovative. While his main quest was improving his own technical knowledge and skills, he also started to realise that PBL required the development of his generic skills as well. Hence, he spent more time with his team members discussing everyone’s progress and made sure they were all up-to-date. He explained research findings and technical content to his team members often at one-on-one and face-to-face meetings, depending upon his team members’ availability. Occasionally he also played the role of a mentor to help Yasar and Suleiman when he realised that they had difficulty in understanding the concepts. He also made sure to give each individual team member the opportunity to discuss their task and learn about the tasks of other team members.

After Semester 1, Suleiman dropped out of the course for personal reasons and Cathy (a member of Team A in Semester 1) and Charlie joined the team in Semester 2. The team now consisted of five members. Jeff was elected to lead the team in a vote. As team leader he decided to share the traffic automation project equally in such a way that each team member had a chance to learn and contribute to the survey of the intersection, coding to simulate the software model of the intersection and to construct an electronic circuit to control the traffic intersection. Jeff determined the team rules and demanded that the team met frequently in order to have enough time for discussions.

Cathy initially opposed the regular meetings and expressed difficulty in coping with such demands due to her part-time job commitments. However, she promised to attend as many meetings as possible. Jeff made himself available to all team members and took the initiative to meet with them individually and also by regularly communicating with them over the phone or by email. Under Jeff's leadership, each team member eventually contributed to all of the tasks.

Every member of the team contributed and analysed multiple ideas that led the team to find more than one solution for the traffic automation problem. During the first two weeks in Semester 2 the team members surveyed many intersections to identify one that had traffic regulation problems. Henry suggested video-recording some of the intersections to analyse them for clarity. Henry and Jeff sketched a diagram of an intersection on paper. Cathy made a fair draft of the sketch that became the blueprint of the intersection the team worked on. Jeff then suggested splitting the software simulation of the intersection equally among all the members in the team so that everyone could have a chance to program each road that lead to the intersection. Thus, each team member worked on programming the simulation of one road that lead to the intersection. Jeff integrated each team member's software code.

Jeff suggested using a design built with two "decade counters" that worked simultaneously in a timed fashion. Cathy suggested the idea of using a "555 timer" instead, which she drew upon from her previous observations of how the dancing Christmas lighting worked. The idea that Cathy contributed was ultimately taken up by the group as their final solution to the problem. Cathy mentioned that discussing the project as a team helped her in connecting her previous knowledge of dancing Christmas lights to the project.

Jeff advised that in both semesters he obtained a High Distinction. While he was proud of his results, he mentioned that it was a bit de-motivating and unclear why the rest of the team members only managed to obtain either a Credit or a Distinction, despite the fact that they had all contributed more or less equally to the work of the team.

To summarise, the membership of this team was heterogeneous. There were local and international students in the team and the team also consisted of a member who was a mature age student. Hence, their previous educational experiences and work experience were also dissimilar. In spite of the diversity, the members in this team were very respectful of each other and worked towards a shared goal. Jeff's perception of the leadership role, his understanding of the requirements of PBL and the assessment system influenced the way the members in this team approached learning individually and in turn the learning that happened as a team.

Members developed a shared understanding of the problem and its requirements and organised their group processes early in both the semesters. They assumed individual roles and willingly contributed to the progress of the team, which lead them to finding more than one solution to each problem. They spent an increasing amount of time in face-to-face contact to discuss their findings and possible solutions to each problem in Semester 1 and the project in Semester 2. The behaviour of the members of this group indicated that they approached learning collaboratively.

6.2.3.2 Characteristics of collaborative learning culture

The narrative of Team 8 presented above indicates that Team 8 consistently adopted a collaborative learning culture with a focus on learning rather than finishing or performing. They decided to engage in considerable face-to-face contact. Students in this team mutually respected each other and involved everyone in every task and every problem. The leader of the team made sure that everyone in the team understood everything that the team worked on and that no one was left behind. He took extra time to explain concepts to those students who had trouble understanding. Thus, the students in this team focussed on collecting evidence for their portfolio by addressing the requirements of the unit learning outcomes rather than by completing the problem. As discussed previously, similar characteristics were noticeable in Team 7 and this team adopted a collaborative learning culture during Semester 1. However, in Semester 2, the characteristics exhibited by this team indicated that they changed behaviours that were consistent with a performing culture.

It was observed that the beliefs, behaviours, actions and approaches to learning of individual team members and the team as a whole influenced what went on in each of those eight PBL teams. While this section focussed on the group learning experiences of the students in eight PBL teams, the next section will focus on analysing and discussing the key factors that led to the different learning cultures that developed in each of the PBL teams.

6.3 Key indicators of different learning cultures in PBL

Students are key participants within any learning environment. Learner-centred curriculum settings such as PBL are particularly sensitive to student participation and engagement as students are given greater responsibility for their learning and are required to work as a team to achieve the outcomes of the course. The diversity of the students' backgrounds and previous experiences, participation in working on the problems and the project, the ways in which they approached learning and the ways in which they directed their learning appeared to contribute to the construction of different learning cultures in this PBL setting. Such attributes were identified using independent case analysis and cross-case analysis.

The key elements of the attributes that were important in identifying the distinguishing characteristics of the different learning cultures and the dimensions from which they were analysed are discussed in this section to illustrate what influenced these different learning cultures. Table 6.3 below is a summary of the key attributes, dimensions and elements discussed here.

Table 6.3 Key indicators of learning cultures adopted by student teams in PBL

Attributes	Dimensions	Elements		
Membership	Team selection	Self-selection, teacher allocation		
	Personal background	Homogeneity / heterogeneity (age, ethnic diversity, local/interstate/ international student, previous school experience and previous work experience)		
Group processes	Communication	Discussion, argument and negotiation		
	Engagement	Commitment, co-operation and collaboration		
	Roles	Freeloader, team worker, co-ordinator and leader		
	Inclusiveness	Mutual respect, support and a mindset to share		
Leadership	Effectiveness of leadership	Understanding of the leadership role (e.g. responsible, authoritative), understanding of PBL, problems and the assessment system.		
	Leadership approaches	Encourage and motivate team members, share responsibilities, peer-mentoring.		
Individual approaches to learning		Surface	Achieving	Deep
	Motives	Extrinsic - passivity, task completion, fear of failing the subject	Extrinsic - successfully completing tasks, obtaining high grades, fear of low grades affecting employment prospects.	Intrinsic – curiosity to learn, personal commitment, accountability
	Strategies	absence, engaging in tasks minimally, not taking any roles or responsibilities	Sharing unequal work loads, encouraging passivity of other team members, working on individual tasks, managing “problem-solving”.	Team-work, brainstorming ideas, sharing ideas and findings, peer mentoring, taking responsible roles, seeking alternative solutions.
Approaches to PBL		Product focussed	Grade focussed	Learning focussed
	Understanding of expected learning outcomes	Finishing problem-solving, finishing team technical report, finishing a portfolio	Team-work, managing problem-solving, developing outstanding solutions for problems, producing outstanding team technical reports, producing an outstanding individual portfolio.	Collaborative team-work, sharing information, learning technical skills and team-work skills, accumulating evidence of learning for portfolio. Solving problems is a means to learning in PBL.
	Strategies for PBL	Splitting the problem into individual tasks, developing solutions for individual tasks finding solutions for tasks on the Internet, completing tasks by using solutions available on the Internet.	Splitting the problem into tasks, team-work, taking shortcuts, sharing unequal workloads to see the solutions completed thoroughly. Making a mosaic of individual contribution.	Collaborative team-work, effective group processes, effective approaches to solving problems, sharing of workload, improving the team’s solutions to problems, finding alternative solutions.

6.3.1 Key elements of membership

As expected in most undergraduate courses at Australian universities, students in the first year electrical engineering degree course included both mature age and school-leavers with varied skills and experiences. Students from diverse educational, work experience, ethnic, linguistic and religious backgrounds came together for this course from international, interstate and local destinations. Their most recent educational experience included high school, vocational education and higher education. Some mature age students had previous experience in engineering or a related field.

By and large, each of the PBL teams in the first year electrical engineering course had membership that was heterogeneous in a number of characteristics. The membership of the team was categorised as generally homogeneous or heterogeneous, based on the characteristics of ethnicity, most recent educational experience, previous work experience and age. Gender diversity was not extensively considered as there were only four female students in the cohort of first year electrical engineering students.

6.3.1.1 Self-selection

During the first two weeks in both semesters, students from diverse social and education backgrounds were asked to self-select into teams with approximately five students in each team. However, some students were allocated to teams by supervisors, possibly because they were unsuccessful in forming teams themselves. Michael in Team 1 was an example of a student who was allocated to a team because other teams did not wish to include him, perhaps because of his declared racial prejudice.

In the first semester, it appeared that students of the same ethnic origin preferred being in the same team. For example in Team 1, students from the same African country preferred working as a team during both semesters. On the other hand, some students thought that their life would be much easier if they teamed up with a mature age student who had previous experience in a similar field. It appeared that most students teamed up based on their experience of fellow students before the course or their brief acquaintance with them while working on Problem 1.

In the second semester, team selection was mainly based on their experience with fellow team members in the first semester. Students who assumed leadership of the team in the first semester appeared to influence the choice of team members for the team in the second semester. These students' negotiation skills and team building skills were evident during this period in Semester 2.

Matt and Edward in Team 2 are examples of influential team members who selected the members of their team. The membership of a PBL team eventually influenced the social behaviour of the members in that team, which was based on the values shared by individuals within the team, the support individuals offered to their team members and the respect individuals held for other members in their team. It appeared that self-selection was generally an effective team selection strategy, since this characteristic was a common factor in the most successful PBL teams.

6.3.1.2 Homogeneity

Team homogeneity (age, ethnicity, previous school and work experiences) in some cases appeared to enhance opportunities to engage in successful PBL processes and thereby in learning successfully as a team. Although students were allowed to select their team members, only a few teams like Team 6 and 7 were largely homogeneous. Members in both of these teams were very comfortable with each other and appeared to communicate freely and without prejudice. This communication allowed them to engage in effective PBL processes. However, when heterogeneity was introduced into Team 7 by their supervisor in Semester 2, the team failed to cope with the situation and in the end was left with only two members to complete the PBL processes.

While team heterogeneity in some PBL teams supported successful group learning outcomes, in most cases it limited their capacity for engaging in meaningful learning activities. This may have been a result of the response of team members to the position and disposition of themselves and other members in their team, that is:

- Their age, previous experiences (e.g., educational and work experiences) and their responses to the diversity of other members in the team (e.g., gender, racial prejudices, school and work experiences);
- Their individual motivations (e.g., career, money or personal desire to the field);

- The roles and responsibilities they assumed in their teams (e.g., freeloader, team worker, leader or organiser);
- Their level of willingness to engage in meaningful learning activities with the team resulting from a shared team perception of the learning needs and the outcomes; and
- Their learning approaches (e.g., surface, deep or achieving approach arising out of their intrinsic or extrinsic motivations).

While most individuals responded positively to diversity in ethnicity and gender, their responses to differences in age and previous experience appeared to depend on their individual disposition and their perceptions of group learning. The age of the members appeared to influence their group learning behaviour and the strategies they used to approach learning as a team in the PBL setting. For example, the students in Team 1 responded to diversity quite aggressively. There were constant arguments arising from racist comments between students of African and Indian origin and sometimes, in the absence of their supervisor, Michael and Ali were involved in physical fights. Similarly, mature age members like Timothy and Rod, in Teams 4 and 5 respectively, who assumed powerful roles in their team, appeared to influence the roles and responsibilities of fellow team members and their individual contribution to their team's progress.

On the other hand, Team 8 was an example of a heterogeneous team that adopted a collaborative learning approach. Members in Team 8 held great respect for the experience and skills of the mature age member (Jarrod) in their team and appreciated his report writing and time management skills. Jeff (team leader) noted that the team benefited from Jarrod's skills and made effective use of his contributions.

Retrospectively, it appeared that homogeneous PBL teams (similar ethnicity, work experience and/or educational experience) were more likely to adopt effective PBL processes and engage in meaningful learning activities than their heterogeneous counterparts.

6.3.2 Key elements of group processes

Group processes or group dynamics are defined by the interpretation of the behaviours of members in a team and the ways in which they interacted in changing circumstances. The group processes adopted by a PBL team indicated the goals of its members. It appeared that the group processes were also influenced by the social makeup of a team, the values they believed in and the norms they set for themselves.

It was evident that the group processes in PBL teams were influenced by the following factors,

- Effective communication (discussion, argument and negotiation);
- Engagement (commitment, co-operation and collaboration);
- Roles (freeloader, team worker, co-ordinator and leader);
- Inclusiveness (mutual respect, support and a mindset to share).

It appeared that successful PBL processes were a product of successful group process and problem-solving processes, which were influenced by all of the above mentioned factors combined with team members' shared perceptions of their learning needs, expected outcomes and assessment system.

Students reported both positive and negative group learning experiences in PBL. Most of them appeared to like learning as a group because they enjoyed the freedom and the flexibility of student-centred learning. Despite this, effective group processes were consistently observed in only a few teams. Team 6, 7 and 8 are examples of teams in which members behaved inclusively, held mutual respect for each other and assumed responsible roles. Most students in these teams adopted deep learning strategies, engaged in discussions with their team members, organised team work, split problems into individual tasks, delegated responsibilities, assumed different roles, shared their learning and worked together as a team in the PBL setting.

6.3.2.1 Communication

Effective communication in PBL teams is defined by the ways in which students initiated discussions, brainstormed ideas and negotiated with team members to assume different roles in problem-solving activities. The strategies adopted by PBL teams appeared to influence communication between team members. It was evident that the teams in which students engaged in frequent face-to-face meetings were more likely to have effective communication. It appeared that some individuals in PBL teams blocked communication because of their poor understanding of the requirements of learning in a PBL setting. Students like Michael and Ali in Team 1 and Edward in Team 2 appeared disengaged during team meetings. They preferred not to attend unsupervised meetings and often only attended supervised team meetings.

Some teams complained that poor access to the PBL studios during times other than scheduled supervised team meetings limited the opportunity for unsupervised face-to-face team meetings. These teams decided to forgo face-to-face unsupervised meetings as they could not be bothered making alternative arrangements. On the other hand, a few teams like Team 6 and Team 8 led by Abdul and Jeff, who were strongly motivated, organised team meetings at other locations such as building corridors or at the University's library.

Although students were required to use WebCT (the University's online learning management system) to communicate during times when team members could not organise face-to-face meetings, it appeared that students used WebCT only when directed by their supervisors. WebCT was seen by some mature age students like Claire in Team 5 as a "cheap way" of getting students to do more work.

6.3.2.2 Engagement

Student engagement in PBL is defined here as the nature of their involvement in the work of their team and their commitment to learning as a team in PBL. Most students expressed a willingness to participate in the PBL context as it allowed them ownership of their own learning. However, their attitudes, behaviours and learning approaches when engaged in learning as a team indicated their actual willingness to participate in the PBL context.

Students participated in this PBL context by attending team meetings, assuming roles and responsibilities and engaging in individual and group learning activities such as allocating tasks, mentoring other members, self and peer-evaluation, writing team technical reports and individual portfolios.

The motivation of individual students, their contributions to their team's progress and the roles and responsibilities that they assumed while they participated in PBL processes indicated the degree of their engagement as learners in PBL. While student participation in PBL appeared to depend on their attitudes, their outlook of learning and perceptions of PBL, their engagement seemed to depend on their knowledge level related to the problem or project, their understanding of the learning outcomes, their perceptions of their own and their team members' skills and abilities and their understanding of the assessment system.

Students who participated minimally also influenced the participation of other students in their team. They often worked to complete only the individual tasks that they assigned to themselves or were delegated to them by their team leader. Some of them followed examples that were transmitted to them by their supervisors. Some other extrinsically motivated students waited for some form of intervention either from their supervisor or from a fellow team member before they even started to contribute.

These behaviours were evident in Ali's team. Ali and his team members did not pay serious attention to their learning and only approached problems at a surface level. None of the members of this team assumed any consistent role or responsibility. They engaged in disconnected activities, including some that were not required of them. Students like Ali and Khadir in Team 1, Edward, Theo and Alex in Team 2, Jay and Muttaiah in Team 3 and Jacob in Team 6 are examples of students who decided that the learning outcomes were unachievable within the given time frame. They used strategies that only required minimal engagement. In some teams student participation was influenced by the attitudes of certain team members. An example is Claire in Team 5, who stepped back from her leadership role when David made some sexist comments about her leadership.

On the other hand, students in other PBL teams increased their level of participation when they received extra support from their team leader or other members in their team. Cathy in Team 8 started to participate in an increasing number of face-to-face unsupervised team meetings when she recognised the value of team-work.

Students of teams with high levels of participation also co-operated well. These students held positive peer relationships with their team members and communicated quite openly during team meetings and attended most supervised and unsupervised team meetings. Matt in Team 2, Claire in Team 5, Bruce and Phillip in Team 7 and Jeff in Team 8 are examples of such students. Their intrinsic motivation and willingness to pursue new learning by investing more effort and determination appeared to influence their level of co-operation and therefore their team's progress.

It was observed that students who co-operated well had a sense of belonging in their PBL team and socially supported their peers. They participated in an increasing amount of face-to-face meetings, organised effective group processes by negotiating their roles and responsibilities and sharing their workload. They actively engaged in solving their individual tasks and also offered help to each other while solving problems. Students' engagement in PBL processes also indicated their commitment to learning in this PBL setting. Some students seemed to feel obligated to complete the tasks individually and thoroughly.

Students like Matt and Claire who played important roles in their teams appeared to contribute most of the tasks and co-operated well with their team members. Yet, only students like Jeff who took an extra step to consistently work together as a team by discussing and sharing ideas and findings and making sure that the team had a shared understanding of all the findings engaged in collaborative learning practices with their team members. Abdul, Haan and Bruce in Teams 6 and 7 during Semester 1 are also examples of students who were most willing to collaborate.

Students who possessed a shared understanding of the requirements of learning in a PBL setting approached and valued learning collaboratively. They approached learning at a deep level and shared responsibilities. They were not only socially inclusive but also valued being included. They appeared to possess a commitment for what was learnt as a team and therefore engaged in many face-to-face meetings to brainstorm, discuss and share ideas, findings and solutions. Therefore, it was evident that only teams in which members collaborated were engaged in effective learning in this PBL setting.

6.3.2.3 Roles

Roles are defined as the identities that individuals assume when they behave, contribute and interrelate with others. Students appeared to assume roles that were consistent with their personalities and experience. For example; Phillip in Team 7 assumed the role of a team worker, Bruce liked delegating tasks, Claire in Team 5 organised work, Timothy in Team 4 always chaired the team meetings and Rod in Team 5 managed problem-solving to meet deadlines. These roles also influenced their social behaviour in their PBL teams.

An example is Team 7 in Semester 1, a homogeneous team with members who knew each other before forming the team. They decided to share their responsibilities and alternated their roles including the leadership role in order to give everyone a fair chance. These students appeared to learn from the strengths and weaknesses of other team members and never underestimated the aptitudes of their team members. It is possible that the team had a shared perception of PBL and believed that everyone's contribution is valuable and important to successfully achieve outcomes in PBL. They also appeared to believe that PBL was an opportunity for learning about these different team roles by participating in them. They appeared to both learn from group interaction and from individual contributions.

It also appeared that individuals in teams which did not have a shared perspective of group learning assumed roles that were unlikely to lead to successful group learning outcomes (e.g. Khadir in Team 1 and Jay in Team 2). Members who contributed most to the work of such teams expressed concern about individual accountability in their team. Some emphasized that some members in their team did little or no work yet received the same mark as those who did a great deal of work. This situation was common in teams that were heterogeneous.

In a few teams mature age students took on influential power-oriented roles. For example, Timothy, the leader of Team 4, encouraged the passivity of the other members of his team. Rod and Claire in Team 5 appeared to control the roles of other members in the team who did exactly what these mature age members directed them to do. Although Claire assumed the role of a mentor in Team 5, she expressed frustration about group learning as she and Rod had to spend an increasing amount of time with at least one other student in their team to ensure the success of their team.

6.3.2.4 Inclusiveness

The level of tolerance exhibited by students to the diversity that existed within their team and their social behaviour in PBL teams defined their inclusive behaviour. Students in most teams appeared to be socially inclusive and tolerant of other members in their team, irrespective of their diverse ethnic or experience backgrounds. Yet, there were a few individuals who did not behave in an inclusive way towards members in their team because of their own racial or sexual prejudices. For example, David in Team 5 appeared to hold sexual prejudices about Claire leading the team in Semester 2.

Students' understanding of PBL and of the expected outcomes within the set deadline also appeared to influence the inclusive behaviour of members in a few PBL teams. Students in Teams 6 and 7, who perceived solving problems in PBL to be a team effort, held a great deal of mutual respect for fellow team members. Their positive attitude and behaviour appeared to have influenced their inclusive behaviour. Students in these teams also appeared to engage in effective group processes by sharing the tasks equally and contributing to the progress of their team by taking up responsible roles.

Working within a group requires students to negotiate and collaborate. However for some students, sharing information was an inconvenience. Some students believed that their sense of autonomous decision-making would be compromised by participating in group processes. Timothy is an example of a student who did not trust their team members in the problem-solving process and did most of the work individually.

While both Claire and Timothy displayed higher levels of knowledge than average first year students, their skills and additional knowledge levels did not have any positive influence in the learning or the solutions to the PBL tasks of other students in their group as they chose not to share their findings with their team members. Students like Claire and Timothy, who perceived that learning in PBL was about solving the problem(s) focussed more on completing the tasks on hand individually and thoroughly. They gave little or no importance to group work as their main aim was to achieve high grades. These students appeared to adopt an achieving approach to learning.

Jeff in Team 8 is an example of an influential team member who believed that his team's success was his success. His inclusive behaviour included making sure that no team member was left behind. Such inclusive behaviour by Jeff is likely to have influenced the collaborative group processes adopted by his team.

6.3.3 Key elements of leadership

The nature of leadership (e.g. responsible, authoritative) and the effectiveness of leadership in organising, managing and directing the team towards a collaborative learning approach were the dimensions from which this attribute was explored. Most students followed the directions of the team leader and adopted the learning approach that was modelled by the leader of their team. There were also instances where the learning approach adopted by an influential team member modified the leadership approach of the actual team leader in that team. Claire in Team 5 is an example of a team leader who offered to sit back when her leadership skill was challenged by David, who demonstrated sexual prejudice against her.

The leadership style assumed by individuals differed from one team to another. From the different leadership approaches that evolved in PBL teams, it appeared that for some students who competed for leadership, the role was all about authority. These students often engaged in dominant behaviour to retain power and status in the team. For example, Michael in Team 1 always competed with Ali in the first semester for the leadership role. A few students like Jeff, perceived the leadership role as a mentoring and a caring role and hence saw leadership as acting as peer mentor, guide and advocate. These students acted to ensure that no one in their team was left behind. They also made sure that learning was shared by discussing and brainstorming ideas regularly and having regular group and individual face-to-face meetings.

Ali and Michael in Team 1 are good examples of the authoritarian leadership style explained above. Both of them competed for the leadership role in the team. According to Michael, the leadership role gave him decision-making rights. He also believed that without controlling other members in the team, problems could never be solved. Ali could not tolerate Michael leading the team. He thought that unless he stepped in and took control Michael would continue to dominate the team.

Matt in Team 2 and Timothy in Team 4 are examples of leaders who took every task on their shoulders. In Matt's case it appeared that he was not able to ensure the participation of all the members in his team. He clearly struggled in his role and decided to take overall of the tasks to finish the problem independently rather than allocating tasks to his team members and waiting for them to complete them. In Timothy's case, he decided to take control of the team because he believed that other members simply did not have the capacity to solve problems. He believed that it would be inefficient to let others to take on the problem-solving tasks. He appeared to assume the leadership role in order to complete the problem independently. It appeared that Matt's and Timothy's perception of the assessment system as rewarding project completion and their personal desire for high grades influenced such behaviour.

Claire in Team 5 believed that leadership was about directing the team to successful outcomes. Accordingly, she delegated tasks to team members and encouraged them to complete their tasks individually. Despite taking up the leadership role and organising team work, Claire mentioned that peer assistance and review worked only minimally in her team because a few members like David were not willing to co-operate. She also believed that time was tight and therefore focused on developing a mosaic of individual contributions as evidence for team work instead of developing a genuinely collaborative solution.

Apart from the nature of leadership and leadership style, the ability of the team leader to manage time appeared to influence success of their team. Team leaders like Jeff and Bruce successfully managed their team's time and engaged in finding alternative solutions to problems. Apart from organising their own time, it was observed that some team leaders also motivated their team members to manage their time.

6.3.4 Key elements of individual approaches to learning

The learning approaches adopted by twelve students in this PBL setting were discussed in Chapter 5. In this section, the factors that influenced deep learning approaches of individuals in this PBL setting are explored. It appeared that deep learning approaches adopted by students in this PBL setting resulted from the combination of factors. This included their personal and learning motivations and participating, engaging, co-operating, collaborating and sharing behaviours.

6.3.4.1 Motivation

The learning motivations of individuals and the strategies they adopted to achieve their motivation resulted in different approaches to learning in the PBL context. Biggs (2003) model of "student approaches to learning" was used to interpret their motivation from the experiences of students in this PBL setting. It was observed that students who were intrinsically motivated possessed a commitment to their learning and their team's learning. Such students made themselves available to their team members and negotiated times for face-to-face contact or communicated on the Internet. They appeared to enjoy participating in the PBL context and reported that the PBL setting gave them ownership of their own learning.

On the other hand, students who were extrinsically motivated only involved themselves in tasks that required minimal efforts. These students did not appear to have a commitment to the tasks that were delegated to them and scarcely bothered about their team's progress. They were also frequently absent for both supervised and unsupervised team meetings.

6.3.4.2 Deep learning approaches

Individual students who were intrinsically motivated used a deep approach to learning. Bruce, Haan, Abdul and Claire are examples of students who were intrinsically motivated. However, Claire and Bruce altered their learning approach when they believed that completing the problems or the project was more important. It appeared that intrinsically motivated students like Jeff used collaborative learning strategies arising out of a curiosity to seek meaning in what is being learnt as a team and displayed a personal commitment to their learning as well as the learning of their team members.

It was also evident that students like Haan and Abdul, who adopted a deep approach to learning, did not compete with individuals within their team and instead offered them support through peer mentoring and peer-evaluation. Such students were also motivated to learn by participating in the PBL environment and engaged in various responsible roles. Students who used a deep approach to learning focussed on improving their solutions by involving themselves in critical group discussions with team members and positively contributed to the learning culture of their team. Jeff in Team 8 is an example of someone who consistently employed a deep approach to learning.

6.3.5 Key elements of approaches to PBL

Student approaches to learning as a team in PBL were influenced by their individual approaches to learning and the shared beliefs and processes adopted by the other students in their team. Student and team perceptions of expected learning outcomes in PBL setting and their strategies to achieve their perceived learning outcomes in PBL influenced their approaches to PBL. Without previous experience of PBL, students constructed their own understandings of what PBL required of them and these varied between students and between teams. Not surprisingly, their previous educational experience and their perception of the way their PBL learning would be assessed also played a key role in their approaches to PBL.

6.3.5.1 Understanding of the expected learning outcomes and strategies for PBL

Most students appeared to understand learning in the PBL setting required them to learn as a group, assume different roles and learn by solving problems. However, during analysis it became apparent that some teams were focussed on finishing the product and in that some teams were focussed on achieving high grades and only one team consistently focussed on learning collaboratively.

The students in most PBL teams appeared to focus primarily on solving problems by finishing individual tasks and then finishing a team technical report, despite the fact that it was not formally assessed. It is likely that misunderstanding of the learning outcomes influenced their team's strategies for learning in PBL. Thus, finishing the problem-solving task by contributing to individual tasks seemed to become more important to most students than learning collaboratively as a team. In some teams students were willing to forgo collaboration because they thought time was tight.

The strategies such teams adopted in PBL included splitting the problems into tasks, sharing unequal work loads and solving the tasks individually by using solutions from the Internet without validating their credibility. Students in these teams did not know the solutions to tasks of other team members. Teams 1, 2 and 3 are example of teams that were focussed on finishing solving problems by developing a product.

Students in teams that shared an understanding that learning in PBL was about developing an outstanding solution appeared to be focused on the quality of their product as well as the grades they obtained in PBL. These teams were more inclined towards "managing problem-solving" by splitting the problem into individual tasks because of their understanding of their learning outcomes. The strategies they adopted included splitting the problems into individual tasks and then making a mosaic of individual contributions to make it appear like team-work. Team 4 and 5 are examples of teams that were focussed on obtaining high grades. The grades that the students in these teams received in Semester 1 strongly influenced their conception of PBL in Semester 2.

On the other hand, the students in Teams 7 in Semester 1 and Team 8 in both semesters shared a focus on learning, shared the workload equally, adopted effective group processes and collaborated with each other by brainstorming, discussing and sharing ideas, findings and solutions. Further, students in Team 8 also engaged in enhancing their team's solutions for each problem and the project by finding alternative solutions or by improving existing solutions.

Team 8 was the only team that consistently focussed on maximising their learning through PBL by accumulating evidence for the achievement of the learning outcomes in their portfolios. Most students in this team used a deep learning approach by sharing the problem-solving tasks, findings and solutions with fellow team members. Students in this team appeared to approach learning collaboratively and gave every team member a fair chance to learn designing, constructing and testing circuits for each problem in the Semester 1 and the project in Semester 2. It is likely that Team 8 took the espoused aim of achieving the learning outcomes seriously and other teams implicitly decided that the real aim (the hidden curriculum) was to "solve" the problem and that this would be rewarded, no matter what the unit outline said. Their shared aim of learning collaboratively made an impact on what they learnt in the PBL subjects in both semesters.

6.4 Summary and conclusion

In this chapter the three different learning cultures that emerged from the observation of eight student teams have been identified. It was observed that without previous experience of PBL and relatively little guidance from their supervisors, students in the eight teams constructed their own varied understandings of what PBL required of them. Table 6.4 presented in the following page summarises the findings of this chapter.

Teams 1, 2 and 3 adopted a finishing culture. Their approach to PBL as a team focussed on maximising the output or product of PBL by finishing the problem or project. There was little evidence of co-operation, collaboration or mutual respect between team members. Students in these teams only attended supervised team meetings. Most of them used a surface approach to learning and were focussed in finishing individual tasks allocated to them by their team leader or supervisor.

Teams 4, 5, and 6 were similar to the first three teams, but for them the focus was also about maximising the grades their members obtained and hence they adopted a performing culture. Students in these teams appeared to co-operate or collaborate well. However they did not value team-work. Some team leaders did not trust the expertise of other team members. Most students focussed on finishing individual tasks but some students who desired high grades were keen in working thoroughly. Students in these teams used either deep or achieving approaches to learning.

Table 6.4 Summary of attributes of different learning cultures in PBL

Learning Cultures	Key elements that influenced the different learning cultures in this PBL setting				
	Membership	**Group processes**	**Leadership**	**Individual approaches to learning**	**Team approach to PBL**
Finishing culture	Either heterogeneous or homogeneous	Poor communication. Little cooperation or collaboration. Most members only attend supervised meetings. Little evidence of mutual respect or support.	Leadership may be contested. Leader directs team members to work individually.	Most use surface approaches to learning. Evidence of surface level engagement on allocated tasks. Most work performed by one or two students. Information is rarely shared.	Focus on finishing individual tasks and finishing individual portfolios. Team product is a mosaic of individual contributions.
Performing culture	Heterogeneous	Good communication. Good cooperation or collaboration. Variable attendance at unsupervised meetings. Members respect and support each other.	Dominant member takes leadership role. Leader allocates tasks and directs other team members to work individually.	Some use deep or achieving approaches to learning, others use surface approaches. Most work is done by one or two members who desire high grades and do not trust the expertise of other members. Engagement on allocated tasks only	Focus on a comprehensive solution to the problem and preparing impressive individual portfolios. Team product is a mosaic of individual contributions.
Collaborative learning	Either homogeneous or heterogeneous	Excellent communication. Excellent cooperation and collaboration. High level of participation in unsupervised meetings. High level of sharing of individual learning. Evidence of peer mentoring and peer evaluation. Members respect and support each other.	Members choose leader. Leader ensures collaborative work on tasks and/or equitable sharing of tasks. Leader ensures sharing of learning arising from those tasks.	Most use deep approaches to learning. Work is shared equitably between members. Members engage in all aspects of the problem or project	Focus on learning collaboratively and accumulating evidence for individual portfolios. More than one solution to the problem may be found. Team product is a collaborative effort.

Team 7 in Semester 1 and Team 8 in both semesters concluded that PBL was about learning as much as they could as a team and they focussed on accumulating evidence for the achievement of unit learning outcomes for their portfolio and hence adopted a collaborative learning approach. Most students in these teams engaged in all aspects of the problem or project and used deep learning approaches. They respected and supported each other, valued team-work and engaged in collaborative or shared work on tasks. The team leader ensured sharing of learning by engaging in peer-mentoring and peer-evaluation.

How is it possible that these three cultures developed in this class when surely what we want is that they all adopt collaborative learning culture? It must be remembered that it was the first year of implementation of PBL in this course and the curriculum was developed with relatively little time to plan a very different approach to teaching and learning. It is also important to note that these eight teams had five different supervisors. So, it is quite likely that these supervisors, who were inexperienced in PBL, had different understandings of PBL and what was required of them as supervisors in a PBL setting.

Perhaps, the supervisors encouraged teams to adopt different strategies, which may have led students to perceive the expected learning outcomes differently. As it happened, the same supervisor supervised Team 4 and Team 8 and yet these two teams developed quite different cultures, suggesting a “hands off” approach to supervision. So what, therefore, do teachers need to do in order to develop an environment that encourages students in the direction of collaborative learning culture? It seems that a key role of the supervisor is to help student teams adopt a collaborative learning culture by facilitation, frequent monitoring and ongoing coaching.

But supervision is not the only factor to consider in this environment. It is possible that the three different learning cultures in this PBL environment emerged as a result of firstly the students’ response to the attitudes, behaviours and learning approaches of individuals who are part of their team; secondly by their reflection of their own beliefs, norms and values and their response to the shared beliefs, norms and values of individuals in their team; and finally by the reflection of their own perception and their response to their team's perception of the environment that is the curriculum, the problem and the assessment system in the PBL setting.

From the data presented here, it is evident that the five attributes (membership, group processes, leadership, individual learning approaches and approaches to learning as a team in PBL) were involved in influencing the different learning cultures that were adopted by student teams in PBL. Although teamwork was a documented expected learning outcome in PBL, some students thought that the successful learning in PBL occurred when the problem or project was completed successfully. It is likely that different understandings of what it means to be a successful team resulted in these different learning cultures.

In conclusion, the important idea that comes out of this chapter is what it means to be a successful team in PBL. This idea will be discussed further in Chapter 9. In Chapter 2, it was noted that the literature propounds the advantages of learning in a PBL setting. Some of these advantages include helping students develop technical skills along with generic skills, innovative skills and cross-disciplinary knowledge. While this chapter mainly focussed on the processes adopted by student teams in this PBL setting, we now turn to what these students learnt in this PBL setting. Hence the second and the third research questions will be addressed in Chapter 7.

Chapter 7

The learning outcomes

7.1 Introduction

The first of the three research questions for this study stated in Chapter 3, which is about the learning cultures, has so far been addressed through reporting on student approaches to learning and the processes adopted by teams in Chapters 5 and 6. The other two research questions focus on how well the PBL environment created for these students lived up to other claims made for problem-based learning.

The two research questions of interest in this chapter are:

- (RQ 2) In what ways does PBL support both cross disciplinary learning and building of a strong disciplinary knowledge base?
- (RQ 3) In what ways does PBL promote innovative thinking?

There are two aspects to the question RQ 2. One is whether the new environment created by a decision to transform the teaching and learning methodology from lecture-centred mode to problem-based mode was conducive to developing the skills and knowledge base that is required of engineers. The second aspect is: does this PBL environment produce the outcomes that are proposed? That is, does this environment produce engineers who have generic skills along with cross-disciplinary and electrical engineering disciplinary knowledge? Team-work skill, which is a key component of generic skills expected of students in PBL, has been explored already by looking at the processes adopted by PBL teams in Chapter 6.

Although, students were expected to adopt collaborative approaches to learning in PBL, in Chapters 5 and 6 it was found that the students' interpretation of the PBL setting, the problems that were the focus of their work and the requirements strongly influenced their approaches to learning and hence the different learning cultures that emerged in PBL. The grades that students obtained and the learning outcomes that they thought they had achieved in the first semester influenced their approaches to learning and thereby the learning cultures they adopted in the second semester.

Hence, the purpose of this chapter is to investigate what students learnt in PBL. The evidence of their learning will be provided by analysing data collected in this study using various qualitative methods with a particular focus on disciplinary and cross-disciplinary knowledge and skills and on innovative thinking. Accordingly this chapter is divided into two sections, the first focusing on disciplinary and cross-disciplinary knowledge and skills and the second on innovative thinking. In each section empirical evidence will be presented to support the claims being made. The findings that are reported in this chapter are based on the analysis and interpretation of data drawn from four main data sources. They are:

- Classroom observations;
- Student portfolios (the product of students' work in the PBL units);
- Students' self-reports collected during the final individual and focus group interviews;
- Findings of the questionnaire and the focus group discussion conducted by Gabb and Keating (2006).

The first two sources are used to describe what students learnt in their first year undergraduate degree course in PBL mode. The last two sources are used to illustrate what students reported they learnt in PBL.

As mentioned in Chapter 4, portfolios were the only form of assessment for the PBL units. These portfolios were collected from the sample of students in this study. For the purposes of grading, the PBL supervisors used Biggs and Collis's (1982) Structure of the Observed Learning Outcome (SOLO) taxonomy to assess the level of achievement of each learning outcome for that unit. The learning outcomes for both the PBL subjects are listed in Chapter 4.

These student portfolios were collected for the purposes of this study after they had been formally assessed by the teaching staff. For this study, the portfolios were then scrutinised for evidence of learning in the broad areas defined by the research questions. The student portfolios were not re-marked in any formal sense, using the learning outcomes defined for each unit. Instead the portfolios were analysed with the intention of identifying evidence of gaining or demonstrating disciplinary or technical knowledge and cross-disciplinary knowledge and of using creative approaches.

Analysis of the data presented in this chapter involved bottom-up and top-down coding both manually as well as using the NVivo software application. The data from observations and interviews were coded using a bottom-up approach and the NVivo software application.

Evidence of disciplinary and cross disciplinary learning was collated in the form of a matrix. Data in the matrix was manually coded to identify themes and patterns. The themes and patterns that evolved from the matrix provided insight into what students actually learnt in PBL. A similar approach was used to group the occurrences of different aspects of innovative thinking in PBL classrooms. Data in this matrix was manually coded by using ideas from the literature for identifying student reflections of innovative thinking processes or products in their portfolios. The findings of the questionnaire and the focus group conducted by Gabb and Keating (2006) that were relevant to the research questions are used to triangulate the findings.

7.2 Proposed learning outcomes in PBL

It was pointed out in Chapter 2 that problem-based learning was developed with several goals in mind. Barrows and Kelson (1995) noted that PBL helps students construct an extensive and flexible knowledge base which extends beyond learning the facts of a domain and integrates information across multiple domains. Thus cross-disciplinary learning is seen as strength of PBL. Developing generic skills is also claimed to be strength of PBL. As indicated in Chapter 2, generic skills identified in the problem-based learning literature include the ability to:

- interact with others in groups or teams in ways that contribute to effective working relationships and the achievement of goals (team working skills);
- use a variety of computer hardware and software and other technological tools appropriate and necessary to the performance of tasks (ICT literacy);

- apply a wide variety of mathematical techniques with the degree of accuracy required to solve problems and make decisions (mathematical skills);
- collect, analyse, and organise relevant and necessary information from a variety of sources (research skills);
- evaluate the validity of arguments based on evidence in order to accept or challenge the findings of others (critical thinking);
- create innovative strategies and/or products that meet identified needs (creative thinking);
- evaluate thinking, processes, products throughout the problem-solving and decision making process by seeking alternative ways to accomplish learning needs (creative problem-solving);
- manage the use of time and other resources to attain personal and/or project-related goals (time management);
- adapt to new situations and demands by applying and/or updating prior knowledge and skills (transferability).

Other proposed goals of PBL include developing effective problem-solving skills, self-directed and life long learning skills, collaboration and intrinsic motivation. It is claimed that PBL is characterised by a learner-centred approach, teachers "who are facilitators rather than disseminators", and open-ended problems that "serve as the initial stimulus and framework for learning". Instructors also hope to develop students' intrinsic interest in the subject matter and emphasise innovative and creative thinking in order to enhance learning outcomes (Clarke, Thomas, & Adams, 2001).

As highlighted in Chapter 2, one of the goals of introducing problem-based learning in engineering is to create a learning environment where future engineers could learn to be innovative and creative in a team or multi-disciplinary group as there is a growing consensus that engineering work places demand these essential skills in professionals who are hired.

Although the research literature suggests that problem-based learning methodology has the capacity to develop such abilities in self-directed learners (Biggs & Tang, 2007; Boud, 1985; Engel, 1991), there is little empirical evidence regarding how PBL encourages creativity and innovation in students (Dunlap, 2005; Evensen et al., 2001; Hmelo-Silver, 2004; Savin-Baden, 2000).

In the engineering education literature such evidence is scarce and fostering creativity is approached with a focus on staff development or subject content design informed through practice (Badran, 2007; N. J. Entwistle & Ramsden, 1983; Tornkvist, 1998; Yu & Shaw, 2006).

7.3 Professional engineer stage 1 competency

It was pointed out in Chapter 2 that Engineers Australia accredits Bachelor of Engineering degree programs offered by Australian universities, provided each program meets certain criteria. According to Engineers Australia's expectations, an accredited professional engineering degree program offered at any Australian University must develop students with a breadth of understanding and outlook, an ability to engage with a wide range of technologies and applications, with sufficient depth in one or more specific areas of practice to develop competence in handling technically advanced and complex problems.

Apart from this Engineers Australia also sets competency standards that allow graduate engineers to practice their profession as "professional engineer stage 1" in Australia. Engineers Australia expects a professional engineer stage 1 to demonstrate competence across a broad field of engineering practice, or engineering discipline, and to have a good understanding of interaction with other engineering disciplines (Engineers Australia, 2008).

It is recalled here that the competency standards set by Engineers Australia for professional engineers were presented in Table 2.1 in Chapter 2. These standards are generic to any engineering discipline and are provided as a guide to certify engineers who graduate from university. Higher education institutions customise these competency standards and fix them into core graduate attributes according to the courses that are offered. In other words, the localised version becomes the learning outcomes that students need to address to successfully complete their course.

7.4 The PBL units of study

At Victoria University it was argued that the introduction of PBL in engineering courses would not compromise technical coverage for generic skills. Parr (2005) stated that PBL was introduced in the School of Electrical Engineering with the aim of enhancing technical learning by placing it in context and in active rather than passive mode. It was expected that PBL would not only enable, but require, the development of the generic attributes as part of the process of learning technical competence.

In the unit of study outline, problem documentation and the course material provided to students (see Chapter 4), the ability to demonstrate team working skills and technical skills were clearly stated. It was also clear that students were required to develop disciplinary knowledge and skills comparable to students studying a similar course at any other Australian university. Furthermore, Problem 3 in Semester 1 and the Project in Semester 2 explicitly required students to demonstrate the ability to utilise a systems approach to design and operational performance and to understand the principles of sustainable design and development.

However, students were not explicitly asked or required as part of their actual expected learning outcomes to demonstrate their ability to think innovatively, or to problem solve creatively. Innovative thinking was not explicitly stated as a learning outcome in the course documents or the problem document for the first year students, but “capacity for creativity and innovation” is one of the professional attributes required by Engineers Australia. It is thus of interest to see to what extent the PBL environment created for the first year electrical engineering students at Victoria University fostered the learning and application of innovative thinking skills.

7.5 Disciplinary and cross-disciplinary knowledge and skills

This section of the chapter deals with what students learnt in terms of disciplinary and cross-disciplinary knowledge and skills. The literature suggests different definitions for the term discipline. These definitions along with other definitions for various words associated with the term discipline were explored in Chapter 2.

In this thesis disciplinary knowledge is defined as the technical knowledge and skills that students attain in subject areas such as electrical engineering area, other engineering areas, mathematics, physics, computer programming, environmental science and business management. Cross-disciplinary knowledge and skills is defined as the application of knowledge and skills across disciplinary boundaries while working on a problem or project. This includes students' ability to apply their disciplinary knowledge in cross-disciplinary settings such as designing, planning, implementing, modelling, testing and measuring activities while solving the three problems given to them in the first semester and the project in second semester.

Clearly, it is not possible that undergraduate students in their first year will attain the extensive and complex knowledge structures of subject experts. Hence, it was important to define understanding in acceptable ways according to the content that is taught appropriate at the stage or year level of their degree course.

Biggs and Collis (1982) described how a learner's performance grows in complexity when mastering many academic tasks using the SOLO taxonomy. They argued that as students learn, the outcomes of their learning display similar stages of increasing structural complexity. Quantitative (pre-structural, uni-structural and multi-structural) and qualitative (relational and extended abstract) stages of learning are noted respectively when the amount of detail in the student's response increases and as that detail becomes integrated into a structural pattern (Biggs & Tang, 2007).

As the SOLO taxonomy describes a hierarchy, where partial construction of knowledge becomes the foundation on which further learning is built, it was used to theorise the dimensions from which students' disciplinary and cross-disciplinary knowledge and skills were analysed. Out of the levels of learning shown in Table 7.2, the multi-structural and relational levels seem to have close correspondence with multi-disciplinary and cross-disciplinary learning respectively. However, all the stages of knowledge indicated by Biggs and Tang (2007) were taken into consideration while looking for evidence of student learning through PBL.

The evidence in the present study was categorised in the form of a matrix of disciplinary knowledge with respect to the levels of knowledge as presented in the following Table 7.1. The data organised in the matrix were collated to report on what they learn in a particular discipline, how they applied their knowledge while problem-solving in that discipline and how they crossed disciplinary from the dimensions listed in Table 7.1. Through bottom-up and top-down coding methods the disciplinary and cross-disciplinary knowledge and skills attained by students were analysed by means of checking their content knowledge and the skills and processes that they used while solving problems in PBL.

Table 7.1 Levels of disciplinary and cross-disciplinary knowledge

Disciplines	Knowledge	Dimensions	Levels
• Electrical engineering • Other engineering • Mathematics • Physics • Computer programming • Environmental science • Business management	• What did they learn? • How did they apply their knowledge in that discipline? • How did they apply their knowledge across disciplines to solve problems?	• Content • Skill • Process	• Pre-structural • Uni-structural • Multi-structural • Relational • Extended abstract

7.5.1 Evidence of disciplinary and cross-disciplinary knowledge

In Chapter 2, it was explained that the term cross-disciplinarity in the engineering literature is referred to as a systems approach or as systems thinking. It was noted previously in this chapter that in this PBL setting students were required to give attention to the systems aspects of the engineering enterprise and its products, and optimise the overall process by considering every element, look for tradeoffs, incorporate diverse kinds of expertise and take the broadest possible view (Skyttner, 1996).

There is little evidence in the data to suggest that students developed strong disciplinary knowledge. There was even scarcer evidence to suggest that individual students combined their knowledge and skills in multiple disciplines to solve the problems in Semester 1 and the project in Semester 2. This is possibly because most student teams either did not engage, or were not encouraged to engage, in face-to-face meetings apart from one supervised team meeting a week to brainstorm ideas, discuss or share their findings and solutions.

7.5.1.1 Pre-structural and uni-structural knowledge levels

Biggs and Collis (1982) suggested that students who simply acquire bits of unconnected information and make no overall sense of that information only accomplish a pre-structural knowledge level. They argued that a uni-structural knowledge level is accomplished by students when they make simple connections. At this level students still do not understand the significance of the information that they gather.

From the analysis of the data collected in the current study, it appeared that students who adopted a surface approach to learning demonstrated disciplinary knowledge and skills at the pre-structural and uni-structural levels (Biggs & Tang, 2007). Perhaps this is what they wanted to achieve. This could be the reason why teams split the problems into tasks and distributed the tasks between members of their team, with individual member picking one that they thought was easy for them and focussed on completing that task individually. Such individual students also reported using processes that were simple to complete, for example, often retrieving and using the solutions that were readily and freely available on the internet without validating their applicability to their own task. The following examples illustrate the processes used by individual students who used a surface approach.

> Ali: First I did research on it on that component. Books and Internet. Books from the library and then when I found the resource, I would select what is important for me. Like which ones I need, then I myself hooked up with Raja to do a bit of maths for the sources we needed to conduct yeah.

> Khadir: No, I did my fair part. I did in the first project, just individual the robot kit, Second project I did my research on AC signal and multimeters and I have written my part for the report. Third project I did, it was the, I did about the rechargeable batteries. Yup and I also did my report, my part of the report and references.

It was observed that some students copied solutions of similar tasks from members of other teams and submitted them for assessment as if they were their own. A few student portfolios had identical structures and a few other students copied their own written work from their Semester 1 portfolio and submitted it for assessment in Semester 2. The following example is Edward's Semester 2 portfolio in which he had copied and pasted sections of his previous semester's portfolio. It is interesting to note that he has not bothered to change the title of the problem from renewable energy to traffic intersection.

> **UL7: Demonstrate an awareness of the uncertain nature of some engineering designs.**
>
> Us as students, were given the opportunity to experience this first hand with the problem of renewable energy came the need for charging circuit to be designed and tested this was completed and our first attempt was embarrassing in more than one way. We failed on our attempt with the design of our circuit containing components with low power ratings it wasn't until we made our second charging circuit that we ironed out that kink but the circuit was still not perfect, it was too complicated it wasn't until the third time we redesigned the circuit that we got it to a satisfactory level.

While some students reported that they found it hard to understand the problem and the expected learning outcomes in PBL, a few others noted that the PBL environment created for them did not encourage them to develop strong disciplinary knowledge. This could be attributed to the individual's prior knowledge, their poor understanding of the connection of different disciplines in PBL problems or their poor understanding of the expected learning outcomes in PBL. The following are examples of student reflection on what they learnt in the first semester PBL subject. These examples illustrate that these individual students feel that they developed little technical knowledge through PBL.

> Khadir: I have done subjects like circuit theory and programming, but I haven't done something like this. That is why I find it a little bit hard.
>
> Rod: As far as electronics theory network things, PBL has given me nothing other than connecting circuits but that in terms of projects that we are doing. So as far as PBL is concerned, it's given me nothing. I don't think I have learnt much from that. Our current problem, I don't think, I am going to learn much more from this problem. I don't think this thing is working.
>
> Cathy: I think PBL should not be for first year students. I think it is a great system, but it's based on our knowledge, using our knowledge to complete projects. And I think that first year, this is my first year, I had a lot of trouble keeping up with the subjects, which is where you get your knowledge from. Because PBL took up most of my time, trying to get all the reports and presentations out of the way, with all the assignments and things like that. So, yeah it's probably better for later years in the course, when you are finding the communication skills rather than having to learn much at the start and having been asked to do all these things without that knowledge that hasn't still entered into your head.

Noticeably, there were also a few free loaders in PBL teams who were interested in everything else other than learning. Such students appeared to lack basic understanding of electronic components or devices that were used by their team to perform laboratory experiments. Abraham, Kumar, Alex and Mark are examples of students who displayed very little knowledge of electrical engineering, computer programming, mathematics, physics and circuit theory when they were asked to explain their contribution to problem-solving during informal interviews.

7.5.1.2 Multi-structural level – Multi-disciplinary knowledge

Biggs and Collis (1982) suggested that at a multi-structural level, students make a number of connections between the information that they gather. However, they miss the meta-connections between them. The following example is a combination of field notes taken during an observation and the transcript of the associated video recording. This example illustrates that students may have acquired a multi-structural level of electrical engineering knowledge. At the time of observation, students in Team 4 were involved in building and testing a circuit for solving Problem 3 (Week 11 of the 12 week semester). In the example below, Timothy demonstrates knowledge of circuit theory, Ohms law in particular. It should be remembered that Timothy was one of the students described in Chapter 5, who was focussed on achieving high grades. It is possible that his motivation influenced the knowledge and skills that he accomplished through the PBL subjects. His knowledge level was clearly superior to that of other members in his team which was comparable to the multi-structural level.

> Timothy: Here we go, now we are getting the same thing. Is this going to go up you reckon? How are you going to measure the current when we got no load on it? We need a low resistor to draw a really nice current. 2 ohms or 1 ohm. At the moment we are doing nothing. If we get 1 ohm resistor what sort of power is that. 12 divided by 1 so we're getting 12 amps. 12 volts divided by 1 ohm resistance. 1.1 watts. There no way this bastard is going to give 1.1 watts. It's going to draw a max out of this. We didn't brain storm together. We did it in the last problem as well. We just jumped straight into it and went 'all right we know'. And then we come across problems. We are continually fixing problems. That's how we are learning man. We need to ask [supervisor]. We are learning but.
>
> Mike: No he might ask us to find.
>
> (As soon as Rajesh connects the circuit to the power supply, an electronic component starts to burn. Students laughed when they saw smoke coming out of the component.)

> Timothy: Come on what's that? (Timothy asked Rajesh).
>
> Rajesh: It is a resistor.
>
> Timothy: No it's a trimpot. Try with this. It shouldn't burn out. Let's put him in. Because, you know how to measure. Connect it in series. Give me that.
>
> Rajesh: Here we go,
>
> Timothy: We are able to draw. We are still dropping 0.2 milliamp is nothing. Yeah 0.2 milliamps into 12. What's 0.2 milliamps into 12? 200 milliamps. That's by 12. Awful mathematicians you are all. It's at most pressure on me man. It is dropping because it is not charged well. The solar panel can give us. So we can only run at 2 volts, not higher. Takes the batteries out (Timothy instructed Rajesh to take the batteries out).
>
> Timothy: Let's build this and order some more parts.
>
> (During the entire time the team was in the laboratory, Arjuna was listening to music on his MP3 player. He was clearly not interested in engaging with other students to conduct the experiment).

Students like Timothy, who had an achieving motive showed eagerness to work on many individual tasks and to acquire the knowledge and skills relevant for those individual tasks. It was evident that they were focussed on attaining specialist skills in the areas of their interest. However, they did not tend to see the interconnection between individual tasks and the overall problem and simply presented a mosaic of the individual contributions when completing the report.

Their approach to problem-solving as a team led to a multi-disciplinary team, rather than a cross disciplinary team, in which individual members were good at certain components of the problem but did not acquire an adequate understanding of the problem as a whole nor did they achieve all of the expected learning outcomes. The following quote is an example of Claire's recollection of her team's approach to solving Problem 3 in Semester 1. It is important to note that individual students in this team demonstrated specialist knowledge in their own tasks, but struggled to share their knowledge.

> Claire: Rod is doing the instrument part of it, I am doing the research and Damien is doing the battery… There is no reward for going the long way because you don't really learn a lot more. There is no real application for what we are doing. Technical side of it is fine but, doing the research is not really upping your skills. If we are doing solar panel for six months then fine. I have done all these research. I am not going to remember… there is so little space for research. You've got ten pages of research and you have to

> condense it to 200 words. No one is going to get the information that I have really researched … we can't just keep looking twice, because we had already done it so just things like that where we have learnt the shortcuts very quickly and we are taking them.

Claire's portfolio was an example of her ability to report her team's findings by accumulating evidence for the completion of individual tasks. She outlined some of the key skills that individuals in her team acquired by writing a narrative of their approach to problem-solving under each unit learning outcomes. The main skills that she reported that her team had developed were soldering, understanding of circuit components, testing of circuits and the technical language for project presentation. She also reported that her team was familiar with using oscilloscopes, multimeters, functions generators and power supply. This suggested that her team had only developed a uni-structural knowledge level related to recognising and identifying electrical engineering equipments.

7.5.1.3 Relational level – Disciplinary and cross-disciplinary knowledge

Biggs and Collis (1982) suggested that students' understanding increases in level of complexity in the relational level as they appreciate the significance of parts of information in relation to the whole. Matt and Luke in Team 2 and Bruce in Team 7 are examples of students who demonstrated learning at the relational level. However, this finding was only apparent in their portfolios. These students did not generally display a relational level of learning during team meetings. This could be attributed to a lack of interest by fellow team members in engaging in conceptual discussions during team meetings.

Their portfolios indicated the list of tasks they had carried out individually, which included a detailed illustration of computer programming to simulate a traffic intersection using Borland C, truth tables to deduce digital counting and timing circuits, Boolean algebra to simplify digital circuit designs to equations to understand their real time behaviour. They also illustrated how they had used their discipline knowledge to build a working model of a traffic intersection. It was evident in their portfolios that these students had reflected on their initial designs and enhanced their solutions by constantly reviewing the outcome. The following is an extract from Matt's portfolio. In this example it is evident how Matt had integrated his knowledge of digital electronics, analog electronics and circuit theory in suggesting a possible solution to the traffic intersection problem. He also discussed the drawbacks of his design after conducting some initial tests.

> After much analysis and deliberation, we [Team 2] have deduced that the main affliction effecting the Plenty Rd / Bell St[8] intersection is the banking of traffic along both sides of the Plenty Rd intersection, causing significant traffic congestion. From our observations, we have concluded that the west side of the intersection is primarily responsible for this build-up of traffic. This is due to the amount of traffic flowing from the prior intersection not having ample time to get through.
>
> The following is a breakdown of our observations. There are two groups of cars, the first being that of Plenty/Bell and the second being that of the previous intersection. This is a hypothetical situation on an average day with mean traffic density…
>
> Thus we propose that a timing modification be made to better suit the two intersections and also increase in the timing on the west side of the Plenty Rd/Bell St intersection. This should be approximately 10-15 secs, when there is a higher traffic density. Therefore we suggest that there is also some sort of counting mechanism spanning the two intersections involved…
>
> Each part of the traffic light circuit and the concepts behind them are going to be explained in the following paragraphs. Full schematics of each section and the entire circuit can be found in Appendix c.
>
> 555 timer: The 555 timer is meant to be used as a frequency generator for two purposes: to deliver 1 Hz of frequency to the counter, so it can count in 1 sec and deliver a high frequency (500 Hz) to the traffic light control in order to avoid glitches in the traffic light display (since the reset on the flip-flops aren't realised by the flip-flop till the next clock cycle. Therefore if a 1 Hz signal is input then two lights will be on at the same time for a whole second. This is extremely dangerous in a practical application and had to be rectified)…

As discussed in Chapter 6, Team 8, in contrast to other teams, was the only team that took a collaborative approach to problem-solving and learning in PBL. Jeff the leader of this team and Cathy are also examples of students who demonstrated relational level learning.

On many occasions it was observed that Jeff ensured that students in his team were engaged in various tasks such as programming, designing electronic circuits from scratch and using Boolean algebra to analyse the behaviour of digital circuits. The team also actively participated in discussions using Fablusi and WebCT, which was

[8] Pseudonyms are used for naming the intersection to guarantee confidentiality.

part of the expected learning outcomes. The following excerpt accessed from Jeff's Fablusi online discussion window is an example of the topics that Team 8 debated in exploring alternative methods of producing green energy during Semester 1. This example illustrates that the team members were also interested in optimising their overall solution by considering every element and looking for tradeoffs.

Figure 7.1 Team 8's discussions on Fablusi in Semester 1[9].

It was also observed that this team brainstormed ideas during unsupervised team meetings and put forward their ideas to their supervisor during supervised team meeting to seek clarification and guidance. They performed laboratory experiments to test, measure and validate the circuit designs and proposed multiple solutions to the problems in Semester 1 and the project in Semester 2. Thus, it appeared that most students in this team not only developed discipline knowledge and skills that were relevant to their individual tasks but also formed an adequate understanding of the topic areas involved and the way they were intertwined in the PBL subjects. For this reason it was concluded that they achieved learning at the relational level.

The following is an excerpt from a combination of informal interview, transcript of a video recording and observation field notes taken during a team meeting in Week 8, Semester 2. In this example it can be noticed that students in Team 8 were able to

[9] Students were already using pseudonyms while debating on Fablusi as they were instructed by their teachers not to reveal their identity. Jeff identified himself to the researcher as the Alfred E Newman of his team in Fablusi.

explain the design process and the methods that they adopted for approaching problem-solving.

> [Researcher: How are you going with your project?]
>
> Jeff: We met on Friday [unsupervised] which was good; I started to explain a circuit diagram and asked if they can share theirs if they have any. Yasar did not come to the meeting. Cathy and I had a couple of ideas. We then went to [specialist teacher] and said that we understand this, but can't get past this one. He [specialist teacher] put it all together and helped us to simplify the idea. So we now have one main counter, 3 bit. Each bit represents a phase. So there will be 6 phases.
>
> Cathy: It was supposed to be a collection of AND and OR gates. But then we decided to go a bit more in depth, you know complex.
>
> (Students soon started a discussion between themselves. Supervisor enters the PBL studio. Students acknowledged the supervisor and continued their discussion.)
>
> Jeff: You are right [said to Cathy], when one of the phases gets called, it will send a signal to the main counter. It happened in the PSPICE simulation. And then using different phases the light transition will change.
>
> Supervisor: What are these circuit diagrams guys?
>
> (Supervisor asks about the circuit diagrams on the white board)
>
> Supervisor: Where did you get these from? Internet or books?
>
> Jeff: Cathy and I made them on PSPISE simulator and it works.
>
> Cathy: We did not use the internet. I was sitting in a dark room for a very long time and used the knowledge from the digital lectures and the notes from [Teacher] after last lecture.
>
> Jeff: We got the idea of using a 256 bit counter instead of using a 4X4 counter. We figured that out from the K-map.
>
> Supervisor: Did you use K-map for each road in the intersection?
>
> Jarrod: Yes, because the light sort of change after X amount of time in every road, I tried to draw K-map for light colours instead of roads. But that has become quite complicated and I could not reduce the equation. That's when I started to draw the K-map for each street in the intersection.
>
> Jeff: We did not like to write it by hand, so I used excel to draw it, is that OK? It gives me flexibility of correcting any mistakes and also if there is a repetition, I can just copy and paste.

Although it was obvious that not all students in this team displayed strong disciplinary understanding in all areas, to some extent they appeared to understand the relevance of different disciplinary areas that they were asked to explore and its application to the problem. For example, students like Amir and Cathy struggled to understand some of the concepts in digital circuit design such as flip-flops and state machines, but, when Jeff offered to mentor them, they participated with great enthusiasm and used those concepts while problem-solving.

To summarise, it was found that most of the first year electrical engineering students acquired the disciplinary knowledge relevant to a particular task that they picked. However, it appeared that they either did not appreciate the connection of their task to the main problem or did not value linking their task with the tasks of other members in their team.

In some cases, student understanding of the assessment system and the belief that their grades depended on the quality of the project outcome, appeared to influence the selection of tasks, for example Timothy worked individually to design, construct and test circuits for all problems and the project. However, when they thought their work load was too heavy to handle, they learnt to take shortcuts and willingly took them to complete individual tasks. These students also blamed a lack of harmony among team members, lack of time to complete the problems and project and lack of support from supervisors for their difficulties in understanding the problem, the process and the expected learning outcomes.

The evaluation study conducted by Gabb and Keating (2006) reported that 87% of the first year electrical engineering students that they surveyed perceived that they were good at locating information of the internet. Seventy three percent of these students reported perceived that they were capable of finding information in libraries and 74% of students perceived that they had a solid understanding of mathematics.

However, the data from observations, interviews and works samples of students indicated that only a few students like Matt, Bruce and Jeff appeared to demonstrate learning at the relational level. By the end of first year only these three students out of the twelve students described in Chapter 5 seemed to demonstrate appropriate levels of knowledge in all the key disciplinary areas such as electrical engineering, mathematics, computer programming, physics, environmental science and business management (project management). These students demonstrated their accomplishments through their portfolios, in which they provided evidence of their cross-disciplinary knowledge of individual components and how they applied, analysed and integrated those components in designing, planning, implementing, modelling, testing and measuring while working on problems and projects.

7.6 Innovative thinking

The notion of innovative thinking and its relevance to PBL was discussed earlier in Chapter 2. It was reported there that creative solutions often lead to innovation and some innovations qualify as inventions. It was also noted that creative processes, traits and motives influences the production of novelty (Cropley, 2001b). Creative problem-solving always involves creativity but, according to Fobes (2002) creativity often does not involve creative problem-solving.

The literature suggests that there are different stages involved in the production of novelty (Cropley, 2001a; Csikszentmihalyi, 1996; Guilford, 1950; Tornkvist, 1998; Torrance et al., 1989; Treffinger & Isaksen, 1994). In particular, aspects of innovative thinking appear to involve a clear understanding of the problem, individual's understanding of their ability to solve the problem, understanding the challenge, understanding the learning needs, accepting the challenge, accepting the learning needs and the knowledge required to solve the problem. It also involves divergent thinking, brainstorming ideas, explaining and sharing ideas and findings with team members, preparing for action, developing a solution, deriving, extensions and exceptions, generating innovative or alternative solutions and building an acceptance of the solution.

While all of Cropley's phases of production of novelty shown in Table 2.1 in Chapter 2 were used to guide data analysis, only creative problem-solving processes and products were taken into account in this dissertation to describe the ways in which the first year electrical engineering students practiced creative problem-solving. Some elements (codes) that were used for coding observation and interview data were applied to analyse student portfolios. Additional codes were also generated during the analysis of student portfolios. All the codes that related to innovative thinking were then categorised according to the stages of creative problem-solving suggested by Yokomoto, Voltmer and Ware (1993) and are presented in Table 7.2. From the analysis of the data, it appeared that several factors may have influenced the way students approached innovative thinking. Some key factors were also important to their learning outcomes. These factors include course documentation (problem briefs and expected learning outcomes), supervisor practices, individual learning approaches and the learning culture adopted by teams.

Table 7.2 Attributes and dimensions of innovative thinking

Phases	Stages	Indicators
• Creative problem-solving process	• Awareness	• Understanding the problem, ability
	• Accommodation	• Understanding the challenge (Learning needs)
	• Acceptance	• Accepting the challenge, knowledge required
	• Articulation	• Brainstorming ideas
	• Assimilation	• Explaining ideas / findings, preparing for action, developing solution
• Creative problem-solving product	• Application	• Generating innovative / alternative solutions, building acceptance

7.6.1 Evidence of innovative thinking

As mentioned earlier in this chapter, the main focus while analysing the data was to find out whether the PBL environment created for students in the first year electrical engineering achieved all the advantages that are claimed for a PBL setting.

The findings of the current study indicated that the degree to which students understood the problems and the expected learning outcomes influenced their awareness of the problem situation. Students' understanding of their own ability to solve the problem appeared to help them understand the challenge and accommodate their learning needs. As noted above and in previous chapters, it was found that students in most teams adopted an approach to problem-solving that involved splitting the problem into individual tasks first and then making a mosaic of individual contributions in the final report. This approach appeared to hinder the development of the stages of innovative thinking such as articulation, assimilation and application listed in Table 7.2 above.

Gabb and Keating (2006) reported in their evaluation study that a majority of the students they surveyed perceived that they were capable of thinking things through and tackling unfamiliar problem situations. While each student's motives and strategies appeared to influence the way they approached and progressed through the six stages of innovative thinking in this PBL setting, other external factors such as the supporting lecture-based subjects, supervisor practices, course documents and expected learning outcomes appeared to strongly influence what they learnt. In this section, the factors that encouraged or hindered students in developing and using innovative thinking are explored.

7.6.1.1 Course documents

As discussed above, the expected learning outcomes in course documents did not include developing the ability to think innovatively or solve problems creatively. The problem documents also did not contain any explicit encouragement for innovative thinking.

As soon as the problem was delivered, the students in most teams observed, split the problem into tasks that was either allocated by their supervisor or by an influential member in their team. Very few students had a clear understanding of what the problem required of them. The following is an example to a student's awareness of the problem.

> It was hard to know what they were expecting and how high they were expecting, what quality? That was not clear in the learning outcomes and also how they were expecting us to go. I think that reflected much more in the second semester. With programming, when I saw the word simulate in the problem document, I was thinking it was game style simulating. It requires, moving objects, reaction times from people and that sort of thing.

A mature age student reported that he decided not to give much attention to the course documents as he perceived that writing reports and the portfolios were the high stake activities in both the PBL subjects.

> I haven't really gone through it much. We have got the portfolios and the reports and that is like a massive amount of work. So I kind of left it for the end.

Students who took a deep approach to learning appeared to understand the learning needs better than the students who approached learning on a surface level. The following are examples of accommodation of learning needs by those adopting surface and deep approaches respectively.

> We just delegate all the sections of the problem to all the people. Where Alex is, he has to be told very much. Someone has to tell him what to do.

> The level of difficulty increased like. Like the first problem was robot building, there was no presentation and there was no report. The second problem audio amplifier, we did have targets to meet. The research, the design and the reporting back sort of thing. I think the quality that they expect has increased.

One student indicated that cues in the problem document helped him identify the knowledge required to solve the problem to some extent. He also indicated that hearing about the topics that were going to be taught in the supporting lecture-based subjects influenced him.

> The C programming wasn't explicit. But the digital was kind of explicit from the company name "Digital Solutions" that was hinted in the problem. I got a sense of - 'ah we've got to use digital technology to solve the problem'. The problem had key words of what they expected us to do. With programming it wasn't explicit. But hearing that we are going to have classes teaching us how to use Borland C++ and how to use graphic header files, it became more clear that, ah, they are wanting us to simulate literally the problem.

7.6.1.2 Supervisor practices

It was observed that most supervisors in PBL asked one student in each team to read the problem out to the rest of their team members every time they delivered a problem. It was also their practice to ask students to think about the problem and the way they might approach finding a solution to the problem.

Sometimes supervisors also showed students a sample solution to indicate what was expected of the students. During Semester 2, some supervisors were observed instructing students on the processes that they needed to follow to arrive at a solution. These instructions included information that students needed to consider to develop a software program to simulate the intersection and learning certain digital circuit theory required for designing the control logic.

Such teaching practices indicated that some supervisors spoon-fed the students with the process and possible solutions instead of asking them the probing questions that would help them to understand the challenge and help them identify their learning needs. The following is a team's reflection on teaching practices in a PBL classroom at the end of first semester. This example illustrates that students were not given an opportunity to identify their learning needs.

> With our last project, the amplifier design we were told that we have to test this, do this measurements and things like that. That was fine. We were basically told what results to get and if we don't get them we were wrong. What we needed for that experiment is someone who showed us how to use the equipments. But we only received last minute directions on that.

Students indicated that they should be given more freedom to choose how they wanted to approach problem-solving in PBL as the practices adopted by their supervisor prevented them from thinking innovatively or creatively.

> [Supervisor] puts a lot more inputs into the meetings now. Like he does a lot of talking in the meetings. So he says some things like how to tackle certain things, how to do different coding and stuff like that. Like he does gives us some hints and stuff like how to do it. He goes to some extent of a bit of spoon feeding if you know what I mean (laughs), because he is basically telling us what to do.

Although the avowed intention was to create an environment where students could articulate ideas, the strategies that some supervisors adopted in the PBL studio negated that notion. They also reported inconsistencies both amongst supervisors in PBL and between PBL supervisors and the teachers of the lecture-based subjects.

> [Supervisor] had commented the other day how they had intended to give us a little bit of a task in the first week and then the week later gave the rest of it. The more I think about it, the less I like the idea. I appreciate he was suggesting that would allow the team members to brainstorm and that is correct. But with projects like this, the first week you do the brainstorming, the second week when you finally get the project, whatever you've thought about it, whatever plans you have for completing the tasks are irrelevant now. Because they have already given you what you are supposed to do, they tell you point for point what needs to be done and how to approach it. So you are not given much freedom.

> Matt: They are on their own. It's PBL then it is the other three and they are linked by another person. if they were all sort of joint together, like the diagram, then it will be much more coherent and they can also add in all the other information required to know for the course not just for PBL. But because they also know we need PBL they can make sure it is hammered in …

Some students reflected that teachers who taught the lecture-based subjects and the language and communication supervisors were far more approachable and useful when it came to helping them to assimilate their findings and develop a solution. However, there were notable exceptions as illustrated in the comments of two students below.

> I kind of got the sense of ah, PBL mainly from [supervisor] and that I can use it to your own level. You choose which is probably your justification. You've got to justify why you've got to that level, how and why you can't do it this way.

> When [PBL supervisor] explains it and you asked him a question, he doesn't tell you the answer. He makes you guess it and get the right answers. But he doesn't want us to give the wrong answers. He just leads us to the answers.

It must be remembered that it was the first year of implementation of PBL in this course and the curriculum was developed with relatively little time to plan a very different approach to teaching and learning. It is quite likely that these supervisors, who were inexperienced in PBL, had different understandings of PBL and what was required of them as supervisors in a PBL setting. Whatever the reason, the practices of some supervisors not only did not encourage creativity and innovation but in some instances strongly discouraged creativity.

7.6.1.3 Individual learning approaches

Although, the course documents and teaching practices did not direct students to engage in innovative thinking, some of the aspects of innovative thinking were observed to some extent in individuals who adopted a deep approach to learning. Student's perception of the learning outcomes and the PBL setting and their prior experience in the subject area are also other possible factors that may have encouraged them to display some of the aspects of innovative thinking.

As an example, Jeff's notion of PBL; that is, his perception that his team's success is his success and therefore a pathway to obtain high grades in PBL, may have influenced his approach to divergent thinking and learning in PBL. He is an example of a student who clearly identified the problem requirement, engaged in learning new knowledge and made associations. He also engaged in making simple diagrams to clarify his thoughts and constantly validated his ideas by sharing and brainstorming with his team members. His belief that his team should succeed for him to be able to benefit from PBL may have influenced his decision to derive extensions and exceptions to his ideas and solutions, thus generating innovative or alternative solutions.

The following is an example where a student's motivation played a part in the strategy that he adopted while problem-solving in PBL.

> I thought I wanted a challenging task in the problem. So I took on the Borland simulation and how to go about and also the statistics of the intersection. I was taking on two section of it. To do this statistics, I videotaped the intersection and played it back which was pretty helpful to count the cars passing through.

Claire and Timothy are examples of students who adopted an achieving approach to learning in PBL, an approach that did not encourage creativity. As their intention was to achieve high grades, they worked on improving their presentation skills and sometimes the quality of their solution to a given problem.

Claire's portfolio was an example of the way she assimilated her ideas and knowledge through learning in PBL. It is important to note that her perception of the key activity in PBL was the production of a high quality report, which could be constructed as a form of creativity but hardly innovation. Nonetheless, she worked hard to understand some of the concepts that her team members were discussing, but she did not focus on generating innovative solutions.

> Rod and Damien were talking about things that I had no idea about. I am working on it. I have told my team members what I know, but that doesn't sound like much.

It was observed in supervised and unsupervised team meetings that Timothy was focussed very much on the product. In the following example it can be noticed that Timothy expressed a desire to work individually, apart from his team members. He clearly indicated a desire to find an alternative solution by suggesting to his team members that he hates working backwards.

> Supervisor: Now, what are we going to do?
>
> Timothy: We need to design
>
> Supervisor: All of you are going to describe on the board what are you going to design and what components are you going to use.
>
> Timothy: what is the best place to get these components? …
>
> Lucas: This is one that goes through all different sequences.
>
> (Lucas shows the team a controller design that he downloaded from an internet website and explained his understanding of that design. While browsing the document that Lucas proposed to the team Timothy mentioned)
>
> Timothy: We need to get the circuit diagram.
>
> Lucas: It's in there somewhere.
>
> Timothy: I don't want to use someone else's ideas. I hate working backwards, because I don't understand it. I would rather do it myself.
>
> What we study in the digital electronics class does not match with what we do now. I have some notes; making out a basic timing circuit is going to be really easy. We can use little push buttons for sensors.
>
> Lucas: that's a lot of work to do. We have maths and physics test to get through.
>
> Timothy: I can get it done by tomorrow.

As Timothy perceived that an outstanding solution would earn him a high grade in PBL, he focussed on producing an outcome that was 'second to none'. With his prior experience and knowledge in a similar field, Timothy appeared to accept the challenge and accommodate his learning needs. He also succeeded in producing an innovative solution by working on his own.

On the other hand, students who approached learning on a surface level never attempted to develop or engage in strategies that encouraged innovative thinking. They were willing to take shortcuts and took them at every possible opportunity. Their understanding of the problem and the expected learning outcomes was meagre to an extent that they perceived learning in PBL was about 'managing' problem-solving. They therefore ignored any learning needs unrelated to their allocated task. Students Ali, Khadir and Edward described in Chapter 5 are examples of such.

The following example is a student's explanation of how his team approached problem-solving in PBL. He indicated that his team often discussed solutions that were found on the internet.

> Student: They just gave the problem and oh yeah, we've got to manage it and stuff. So I think I had to delegate certain parts of the problem to everyone. We got the problem and we just delegated all the sections of the problem to all the people. We research different parts that we are assigned or what we assigned for us individually and then just run a weekly meeting which will go for an hour or so to elaborate on what we found.
>
> Interviewer: What are your findings? Are they ideas or solutions?
>
> Student: They are more like solutions, like what other people have come up with on the internet. We just research them and then like try to do it.

To summarise, observably, surface approaches adopted by students while learning in the PBL setting and splitting the problem into tasks and solving tasks individually did not promote any of the aspects of innovative thinking. It was evident that, some of the positive factors that offset the scene for innovative thinking include a good understanding of the expected learning outcomes, a deep approach to learning and prior knowledge. The stages of innovative thinking adopted by a few students who were innovative include awareness of the problem situation, accommodating the learning needs, accepting what is required to be learnt and how, brainstorming ideas, sharing ideas and findings with team members and developing extensions and exceptions to the initial findings.

7.6.1.4 Learning cultures

From the analysis of the data, it appeared that the learning cultures adopted by PBL teams, their group processes and their approaches to problem-solving were also indicators of the extent to which innovative thinking was used in PBL classrooms.

Positive group learning behaviours appeared to encourage the development of some of the aspects of innovative thinking. As discussed in Chapter 6, Team 8 was the only team in which students consistently adopted a collaborative learning culture, thanks largely to the work of the team leader. It was also the only team that demonstrated all of the stages of innovative thinking. The result of this was the solutions developed by this team were identified as unique by their supervisor. It is possible that Jeff's leadership encouraged effective brainstorming among team members and thereby influenced their capacity for innovative thinking.

In a few teams for example, Team 6 and 7, that worked well together but did not generate innovative solutions, it may be that they could have adopted creative problem-solving if innovative thinking was encouraged by their supervisors. It is possible that their motivation to perform led them to avoid innovative thinking as risky. It should be noted that these teams managed their group processes quite well in spite of having members who were unwilling to co-operate. The following excerpt from an interview could be interpreted as a risk-averse response to failure of the problem-solving process in a PBL team.

> With PBL the way it is set out is basically, you are in a team and you have to work together as a team to accomplish the goals or solving the problem, even though the problem may not be solved, the idea is by working together with the team and communicating with the team members, you can actually manage to like, if you can't fix the problem, but there might not be a solution to the problem. So as a group you can discuss that and state the actual conclusion or the problem.

It was found that, student teams demonstrated some of the stages of innovative thinking only when they engaged in face-to-face meetings. The following example illustrates that face-to-face meetings provided an opportunity for team members to articulate by discussing and sharing ideas and findings and thus appeared to enable innovative thinking. Students were very positive about expressing their thoughts confidently.

> I think everyone is the same actually. We sort of bounce ideas off and then, that's the main advantage of being in the group. People chuck their ideas and they get criticised really constructively until you find out about which ones you think are really the best ideas.

These teams also engaged in an integration process by sharing some of their findings when more than one member in the team was engaged in a similar task. The following is Bruce's recalling of how a few members in his team (Team 7) exchanged ideas.

> Like me, Lachlan and Jacob, we were all doing Borland. So we all had like our mini meetings and stuff. And then I sent Lachlan parts of my solution and he sent me part of his solution and now we've got really good solution and we've just got one more thing to do and it's gone pretty good.

However, it was also found that some students in teams that adopted a performing culture did not even get a chance to participate in solving the problems. While in some cases influential team members were responsible for creating such situations for members in their team, in other cases it appeared that these students needed more support and coaching for understanding the learning needs and processes for solving the problems. The following examples illustrate how some students were deprived of a fair chance to engage in problem-solving.

> Damien in our team doesn't get much work at all. He is very capable and pretty much everyone else in the team will be getting a whole lot of work. David is a programmer, Rod has done all the circuits and stuff; he is a technician and me writing the reports. Other team members don't get to contribute, where as they must as much as they could or should.

> One of the members in our group, she is very enthusiastic and very keen. She wants to do it right but, she doesn't seem to have the mental capacity or the experience to be able to fulfil the tasks that we give her.

There was no evidence to suggest that students in teams that adopted a finishing culture by focusing on finishing the tasks with minimal efforts developed or used any of the strategies that encouraged innovative thinking. For example in the following excerpt from a focus group interview conducted in the second semester, Khadir vaguely recalled the process his team followed to approach problem-solving in PBL.

> First we do brainstorming to see what exactly the problem is, and then I will put into how I really understand it. Like in a way if I understand the problem, I can do this research. Yeah, so we look at the problem and try to work out the solutions and then do the research. Try to find out which solutions and pick which ones would be better suited.

To summarise, the findings from the data suggest that students who collaborated or co-operated with the their team members to identify successful group processes and approaches to problem-solving, developed and used strategies that encouraged all, or at least some, of the aspects of innovative thinking. While the expected learning outcomes in the PBL subjects were key factors that hindered the development of the aspects of innovative thinking, other factors such as the type of problem, effectiveness of supervision, students approaches to learning and the team's learning culture also appeared to constrain the development and use of aspects of innovative thinking in this PBL setting.

7.7 Summary and conclusion

The findings about the learning outcomes of students in a newly created PBL engineering setting were presented in this chapter. The learning outcomes of students presented in this chapter were analysed from data collected through observations, interviews and work samples of students. Factors such as students understanding of the problem, their ability to identify and accommodate their learning needs, their understanding of the expected learning outcomes and their understanding of learning as a team appeared to influence the learning that happened in this PBL setting.

The findings presented in this chapter indicated that most students in this PBL setting acquired disciplinary knowledge relevant to a particular task that they picked. Observably, students who exhibited this learning behaviour were members of teams that adopted a finishing culture or performing culture. It was found that most students in these teams were only able to make simple connections of their individual task outcomes with their team member's outcomes. It was evident that they did not know the relevance of their tasks to the problem as a whole. Students who were motivated to achieve high grades were able to make a number of connections between their own tasks and the tasks of their team members. This is possibly because they either solved the entire problem by themselves or because they integrated individual findings for their team report. A few such students also demonstrated the accomplishment of strong disciplinary and cross-disciplinary knowledge.

On the other hand, students in the team that adopted a collaborative learning culture demonstrated an ability to appreciate the significance of their individual tasks in relation to the problem as a whole during team meetings. They used strategies including brainstorming, explaining and sharing of ideas, information and findings. They also worked on finding alternative solutions to problems, which indicated that this PBL setting implicitly promoted the benefits suggested by the advocates of PBL including the development of cross-disciplinary knowledge and innovative thinking.

In conclusion, it appeared that if these learning outcomes had been explicitly mentioned in the expected learning outcomes of the course, it would have been likely that an increasing number of students may have acquired and achieved those learning outcomes. That way, perhaps, supervisors may also have encouraged students to adopt strategies that promoted innovative thinking and valuing the integration of knowledge of different disciplines. The findings presented in this chapter will be triangulated through observation of the eight randomly selected students in a simulated engineering situation presented in Chapter 8. It is expected that this activity will provide further evidence to what students may have learnt through PBL and how they apply their knowledge and skills in a new situation.

Chapter 8

The group problem-solving activity

8.1 Introduction

In Chapters 5 and 6, the ways in which twelve individual students worked in their teams and the ways in which their teams worked were described through reconstruction of data collected from observations, individual interviews, focus group interviews and their work samples. In Chapter 7, some of the learning outcomes achieved by these students and the factors that influenced these learning outcomes were described. In this chapter, the findings of a simulated engineering situation named the 'group problem-solving activity' involving eight randomly selected students will be presented. These eight students have been the focus of this dissertation and their attitudes, behaviours and learning approaches were described and analysed in Chapter 5 along with four others. This problem-solving activity was a simulated situation and was conducted at the end of the first year after the students had completed their regular course requirements in Semester 2; that is, their classes and their examinations.

The purpose of this activity was to gather information about students' application of generic skills, disciplinary and cross-disciplinary knowledge and skills that they may have developed in the first year of their degree course through PBL. Particular attention was given to generic skills such as those involved in communication, team work, time management and research. In addition, this task required innovative thinking for example, a new idea, improving on a finding or finding alternative solutions. It also required the application of disciplinary knowledge (electrical engineering, other engineering knowledge such as mechanical engineering, ICT, mathematics and physics) and the use of cross-disciplinary knowledge; that is, the ability to apply their knowledge of different disciplines in solving the problem. The findings of this activity will be used to triangulate the findings reported in Chapters 5, 6 and 7.

This chapter has three sections. The methods for the group problem-solving task and the problem that was chosen are presented in the first section of this chapter. In the second section, the data from the problem-solving task are presented as two cases of teams A and B. In the last section of this chapter the findings of the analysis of the two teams; that is, the eight students' attitudes and behaviour in a different team and problem-solving situation and how the knowledge and skills that were learnt over a period of one year in PBL was applied in a new (simulated) situation are discussed in detail.

8.2 The group problem-solving activity

In order to gain an insight into how the students approached problem-solving and applied generic skills, disciplinary knowledge, innovative thinking and cross-disciplinary knowledge, a problem-solving activity was designed. The eight randomly selected students were organised into two teams on the basis of their availability to participate in the activity and were observed working in these new teams. These students had not worked as a team during the course, although some had worked previously in a PBL team with one of the students in their team for this activity. The students were asked to undertake this task at the end of the year after they had completed all of their assessment tasks for the course.

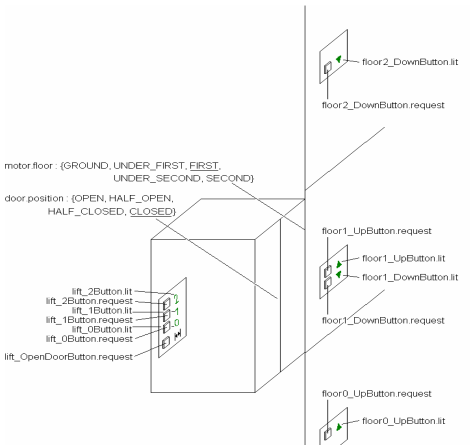
8.2.1 The lift problem

For this group problem-solving activity, a problem (advanced lift controller system) was designed and students were allowed one hour to work on a solution to this problem. Students were given access to books relevant to the problem, computer access and access to the Internet. They were also provided with links to sample websites such as the University's electronic library and other technology-related websites on the World Wide Web.

At the time this activity was conducted, students had studied computer programming, circuit theory, electrical fundamentals and digital electronics in conjunction with two units of study in PBL mode. Therefore, this problem was relevant to the engineering content and skills that were taught in the course.

The problem and the expected outcomes were all specified in detail in the problem documentation (see Appendix 7) that was distributed to the student teams at the start of the activity. Students were asked to assume that the university where they were studying had hired their team to propose an advanced lift controller system that would bring significant commercial, technological, operational benefits to the lift industry in terms of reliability, cost saving and ride quality.

To constrain the problem, students were advised that the lift served three floors only. They were asked to consider the controller, as well as the necessary sensors and actuators to operate the lift. As the controller responded to requests from a panel of buttons inside the lift and a panel from outside on each floor, they were also asked to consider parameters such as the mode of operation; that is, whether the lift is going up, going down or passive waiting for a new call. Considering these parameters were vital as the controller sends messages to actuators that control the lift motor and the door. A simple diagram of the lift operation was also provided. Figure 8.1 illustrates what was required of students in the group problem activity.



Problem statement

You have been hired by an Australian University to come up with an idea to design an advanced lift controller system that brings significant commercial, technological and operational benefits to the lift industry in terms of reliability, cost saving and ride quality.

Constraints

- Lift served three floors only
- Controller – control buttons from inside and outside of the lift
- Sensors – doors, speed, movement
- Actuators to operate the lift – communication between controller

Task

- Discuss the problem and brainstorm ideas
- Decide on the ways in which you would retrieve any information required
- Share the information and propose innovative solutions to the problem
- Solution could just be ideas and need not be a complete solution

Figure 8.1 The LIFT problem for the group problem-solving activity

As students were allowed only one hour to work on a solution for this problem, the activity was designed so that students were not required to arrive at a definite outcome. However, they were asked to brainstorm ideas and, as a team, to decide on ways that they would obtain and share information and to formulate and suggest possible innovative solutions to the problem. Students were reminded that the solution could just be ideas and need not be a complete solution.

8.2.2 Data collection and analysis

The data collection and analysis for the group problem-solving activity are explained in Chapter 3. This activity was video-recorded and the video-recordings were transcribed before analysis. The methods used for analysing the data collected from this activity involved description, analysis and interpretation. A summary of the methods used for the group problem-solving activity is shown in the following figure (Figure 8.2).

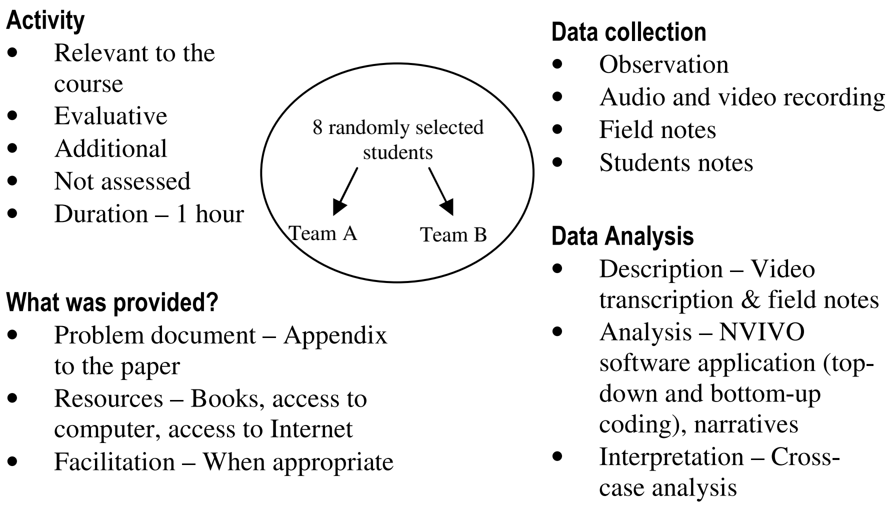


Figure 8.2 Methods for the group problem-solving activity

8.3 Students in action – a reconstruction of the observation data

Each team consisted of four students: Claire (from Team 5), Matt (from Team2), Bruce and Phillip (from Team 7) formed Team A; Jeff (from Team 8), Theo (from Team 2), Ali and Khadir (from Team 1) formed Team B. I informed and reminded students in both the teams of the expectations, timeline, the tasks and the resources that were made available to them at the start of the activity. At the beginning of the activity, I instructed students in both teams to read the problem for the first five minutes and discuss the problem for the next five minutes. I asked them to brainstorm ideas and decide on ways to retrieve the information required and process the information for the next 40 minutes. Students were instructed to formulate their ideas and suggest possible solutions to the problem during the last ten minutes.

8.3.1 Team A

Bruce and Phillip had worked together as a team during their entire first year course. Claire and Matt belonged to different PBL teams. Apart from Bruce and Phillip, other students in Team A had only minimal contact during the year. The personal and academic backgrounds of these students were described earlier in Chapter 5. Claire was a mature age student; Matt had a vocational qualification in electronics; Bruce and Phillip were school-leavers but had one year of university experience.

At the beginning of the activity the students were very quiet and did not speak to each other. After they were asked to introduce themselves to each other they did so with good humour. The atmosphere in the team seemed pleasant, inclusive and encouraging. I prompted the team to work systematically and to understand the problem. I also reminded them of the expectations, timeline and the available resources. The following transcript is an excerpt from the beginning of the video recording of Team A. The instructions that were given to students at the start of the activity were:

> Like I said before, I would like you to carefully read the problem. The first 10 mins is for you to understand the problem and ask me any questions then and there. In the next 40 minutes you are required to discuss the problem and brainstorm ideas as a group. You are also required to decide as a group what ways you'll get the information needed and share the information. In the final ten minutes, I want you to formulate and suggest possible innovative designs as a group to solve this problem.

Matt initiated conversation within the team and drew everybody's attention to key ideas such as the construction technique, operation methods and the electrical, electronic and mechanical components that might be required to control the lift's operation. The rest of the team members waited for him to finish expressing his initial thoughts about the problem. When he mentioned that it would be possible to summarise the problem using truth tables, he indicated that he was reflecting on the validity of his ideas. In the following video-recording transcript, Matt expressed his ideas to his team members by recalling the knowledge that he had gained in digital electronics.

> Matt: I am looking at an expanded version of a state machine, but basically a state machine I am seeing. Like we need to read more to evaluate, but what I can see is, just looking at these (points to the notes that Kelly had taken from the diagram), we can use like a truth table, to set out some of the basic necessities of these, that's before it goes into the priority, kind of thing.

Claire and Bruce helped the team think about the problem more deeply and pointed out other key ideas that were implicit in the problem, such as where the lift design was to be implemented and the number of passengers. They also discussed the need to decide on the type of mechanical construction for example, cable, hydraulic, etc.

> Claire: We need to worry about this safety and all too much, Michael said not much, maybe not, coz it is mechanical. We need to look at the inputs to the controller to bring the elevator up and down and stuff like that and we also need to include what state the door is in.
>
> Bruce: Yes, and also the door sensors to make, like the curtain, make sure no one is breaking the curtain … so are we going for a hydraulic lift or a cable lift? Maybe we should find out which one is faster.

Students in this team initially expressed anxiety about the decision-making process. Little by little, however, the students became more confident and supported each other's attempts to explore the problem. They approached decision-making by thinking, making sense, intuiting and also by using non-verbal cues. Soon after this, they started organising the group processes. At times Claire asked questions to refine Matt's thinking and to make sure that the team wasn't deviating from the topic:

> Claire: So, going back to the beginning, trying to design something that will respond to a set of inputs and -
>
> Matt: [Interrupts] So there is going to be some sort of control circuit
>
> Claire: Yeah, that is going to analyse the set of input data, and then outputs to the lift basically.

Clearly, within minutes all team members assumed roles within the team. Matt chaired the session, Claire set tasks and organised it. Bruce showed some interest in leading the team, but then took up researching. However, Phillip's role in the team was mainly passive. He did not converse with other team members and remained silent. Most of the time during the meeting, he kept reading the problem documentation and occasionally skimmed through one of the books that were provided. His body language indicated that he was consciously or unconsciously blocking communication with the rest of the team. Bruce tried to include Phillip in the conversation by interrogating him about his lack of participation. But, the rest of the team did not seem to bother about Phillip as they were fully immersed in the problem-solving process. The following example shows that, while Claire organised team-work, Bruce tried to lead the team and also to draw Phillip into the group's conversation.

> Matt: So there is lots of safety, door sensors, doors we'll look at the doors and what else is there?"
>
> Claire: Energy efficiency, I don't think we would be able to go that far into it though. We are not actually having the, given the time limit. [Reads the problem out loud] advanced lift controller system, that brings some significant saving, and improves the ride quality.
>
> Bruce: All right, All right, we are required to discuss the problem and brainstorm ideas. Well shall we do that first?
>
> Claire: Yes.
>
> Bruce: What do you think Phillip?
>
> Phillip: I am just trying to think at the moment. Would it be useful to customise the timings maybe something like, how long does the door stay open and stuff like that? Just trying to think... umm… Like if it is not really busy maybe we can get the doors closed quicker.

Soon after discussing the problem and the key points that needed addressing, Claire restated the ideas, themes and feelings that were expressed.

> Claire: We need to look at the inputs to the controller to bring the elevator up and down and stuff like that and we also need to include what state the door is in.

She also summarised the tasks and assigned herself a task. She decided to analyse the problem situation and hence, started to find information about the lift's operation techniques from the Internet.

> Claire: I want to go online and look at 'How Stuff Works' website and I want to look at running the overall operation. I am sure we should be able to find something out there. Maybe even a circuit laying out as to how it is done. Is that ok? I will quickly have a look at 'How Stuff Works' to see if I can get a rough circuit diagram or something so we can have a look at how to do that part of it and then we can maybe worry about mechanical factors or safety aspects.

At this instant, Claire indicated the direction of her intentions in problem-solving and her preferred method of information retrieval to the team. Her comments and actions indicated that she was not only making use of the information that was provided in the problem document, but also choosing the one that she perceived as the most effective method to retrieve information that was required to solve the problem.

While Claire browsed the technical websites on the Internet, Matt applied his knowledge of Boolean algebra to mathematically solve the operation of the lift between the three floors and the door's open and close mechanisms. It is possible that he had gained this knowledge from the first year degree course. While mathematically solving the problem, he interrupted, cracked jokes, made remarks that were often humorous, raised some valuable questions about safety mechanisms and discussed improvement to the efficiency of its operation. Matt's comments about safety directed the team to collectively engage in divergent thinking, focusing on ideas that were different from previous ideas.

> Matt: We can also have the other original safety features as well, like the things that we were talking about before, like we can have the special catch, we got the things that grabs on to the sides or the cable and we can also have in the bottom in case all of these fail, we got a series of hydraulic syringes that when the lift hits that pushes that basically squirt out of the floor just to slow it down so that there is a chance to survive. There are all sorts of back up.
>
> Bruce: It is all like a myth, but it so cool. We can spend half a day probably talking about the safety of it. [Laughs].
>
> Matt: There is heaps man, but the best part is just undo one bolt and go, I think I have to be saved with the entire safety mechanism. That was the coolest one. [Giggles]

Initially Claire and Bruce were only looking at how lifts operated and what mechanisms existed. At one stage when the team struggled to take the discussion further, Bruce recommended that the team undertake a deeper analysis of the problem to clarify concepts. He asked probing questions that not only called for the team to stick to a plan and execute it, but also questioned his self-awareness and the team members' knowledge. At one time, Matt suggested that they could design a magnetic lift that operated on magnetic flux similar to the operation of the Maglev train in Japan.

> Matt: Let's go the whole way of saying magnetic lift that operates on magnetic flux.
>
> (Claire and Bruce laughed as they heard him say this)
>
> Matt: Let's say it's got whole bunch of electrical inductors whole way up the wall. Poles all the way up with magnets and pushes up with a level of magnetism.

Bruce: Oh yeah, Maglev, they go like couple of hundred k's an hour or something.

Even though Matt's idea was vague, it introduced an approach quite different from the mechanism that the team had been discussing. His new idea acted as the turning point in the team discussion. Each team member had a different perception of this new idea. As Matt's thoughts were at a preliminary level, he expressed his perceptions using gestures and body language that helped other team members make sense of his thoughts as they interpreted his gestures. The team members then reflected on their past experiences of this concept, which scaffolded some innovative thinking. In the following example, it can be noticed that the students reflected on their prior knowledge of magnetism in physics, while attempting to connect it to the problem.

Matt: There is also a way for safety mechanism. The way of doing it is, you can like have a magnet in a pit and you can also have a magnet in the bottom of the lift, and if it falls,

Bruce: If it falls it falls slowly.

Matt: It's probably going to hit, but as the induced magnetic force gets stronger, it is going to influence the repulsion, so if you have a south and south and the north the electric, no they all have to be the same to push it up wouldn't they and as soon as the fault occurs,

Bruce: How about programming the magnet to change polarity? On the line of curve or something, if error, then just change the bottom one to the same polarity as that of the magnet under the base of the lift [Laughs]. That's an idea. Yeah?

Bruce was captivated by Matt's ideas and he joined Matt in building a stronger understanding of the concept. In the following excerpt of a combined video transcript and field notes, it can be noticed that students made fun of ideas that they came across while wandering in different directions to identify their learning needs.

Bruce: Maybe we can include, hmmm, thinking, thinking… Yeah maybe like a plough that comes from the back of the wall and then pushes everyone out. [Students laugh]

Matt: Something that tips everyone out.

(Looking at his computer's screen, Bruce talks)

Bruce: I read an article that says, Maglev elevators are to be out by 2008. Look there is such a thing. It uses basic properties of physics properties of magnetism such as, attraction and repulsion to give the object momentum.

Claire interrupted and pointed out that their solution needed to be cost effective.

Claire: That would be more expensive wouldn't it? It is supposed to be cost effective, look at the question, cost saving.

This put a stop to the discussion between Matt and Bruce and soon Bruce realised that more information was essential to argue any point. During his research Bruce came across and discussed important information about the life span of an elevator. He shared with the team statistics about how much a lift would have travelled in 10 years of operation and how many passengers it would have transported. This directed them to research this topic.

> Bruce: I am typing 'elevator plus (+) cost saving'. They are talking about gearless elevators here and the eco disk, a control system that reduces passenger waiting time and improves the ride and mentions that the system incorporates a generic algorithm with multi-target optimising capability, employs artificial intelligence and fuzzy logic to carryout the task. After operating for 20 years an elevator could have travelled half a million kilometres. You know? And could have carried 10 million passengers.

Claire and Bruce started to find more information during individual study about the cost involved in the materials, the design and the construction, control techniques, safety mechanisms and even using recycled materials for construction to reduce the cost. Every time they came across new information, they discussed it immediately. Matt moved on from the truth table approach to the state machine approach to solve the problem. However, he did not spend any time on research. Instead, he appeared to learn by listening and by questioning Bruce and Claire. Phillip flipped through a few books but was clearly not engaged.

Bruce interrupted Phillip and asked him to help write down a few points about the energy efficiency of lifts.

> Bruce: It employs a permanent magnet synchronous motor in combination with a frequency control and a gearless construction. That helps?
>
> Matt: No.
>
> Bruce: No, it doesn't.
>
> Bruce: Maybe we should buy one of these, the eco disk; it is 35% energy efficient and a smooth quiet ride.
>
> Bruce: Oi, write down. [Bruce looked at Phillip and tapped on the paper that Phillip was writing something else]

Phillip instantly agreed and started to help Bruce. While helping him, Phillip came across a few things that appeared to be of interest to him. When Claire responded to a question from Phillip, he slowly started to participate in the discussion.

> Phillip: Just a quick question, how tall will be three floors?
>
> Claire: Depends on the floors.
>
> Bruce: Seven, 20, 30 feet may be.
>
> Phillip: Do I look American?
>
> Matt: That's the best I have heard the whole year.

He drew upon an idea from a television show, "Futurama", that he watched as a kid and explained with gestures that there were tubes in that show which flew straight up.

Claire thought that his idea was "awesome".

> Claire: It would be less than 19 meters, 18 meters probably, considering 6 meters for each storey.
>
> Bruce: Should be sweet. Or cut a hole in the floor and have a slide from the second floor to the first floor so the elevator doesn't have to go down.
>
> [Everyone laughed at this joke].
>
> Claire: That would be much faster.
>
> Phillip: That's something like the Futurama stuff, there are like tubes and the tubes go whoop and go straight up. That was my favourite when I was little.

She browsed the Internet to find further details and came up with the idea of a pneumatic vacuum lift.

> Claire: I want to do a vacuum lift. That will be cool
>
> Bruce: Yeah pneumatic, are you on the same page that I am?
>
> Claire: I don't know [reads out] Daytona elevator
>
> Bruce: No.
>
> Phillip: It is like Futurama.
>
> Bruce: This pneumatic vacuum lift uses suction to lift passengers.
>
> Matt: Does it actually work?
>
> Claire: There is still actual thing in there, yeah, yeah it does.
>
> Matt: That will be cool, but that sort of suction will probably not allow you to breathe.

All of them then worked intensively to reach a common understanding. They had rich discussions to uncover misunderstandings and built a connection between the bits of information contributed by individual members.

> Bruce: Well we discussed a number of elevators.
>
> Matt: As cool as the vacuum lift it is, it's nowhere near feasible.

Claire: Why not?

Bruce: You can only fit one person in it.

Matt: Yeah, you can only fit one person in it.

Claire: Why can't you make it bigger?

Matt: Because of the dimensions, because of the sucking power that is required to pick a lift that has more people, serious it is a lot.

Bruce: And the more people we have,

Claire: We can tarry the weight, that's what I am saying, is it?

Matt: Yeah that's because it is a tight tube, if the pressure is increased with the size of the tube, if you make it wider, the suction required will be,

Bruce: It looks like it is an exponential increase in the pressure. It's an exponential pressure increase with the number of people in it.

Claire: Yeah I know what you are saying, but given that it is a much cheaper option.

Matt: Well thinking that it going to be exponentially, think about it might exponentially increase, it is obviously going to be dramatic.

Claire: It depends on the usage of it.

Matt: I think, by employing vacuum, keep the same size or a bigger one, but basically have a bank of these things, like may be six of these tubes in a row.

Bruce: Although as we said at the start, the problem doesn't tell us the people load on this thing. It's just asking for a solution.

Matt: We can give two answers, with many people count, but if it's like high, if a lot of people using it then, well the problem does say that it is for Vic Uni.

Claire: No, it says what the project is for, it doesn't say [grabs the problem to reads out] you have been hired by Vic Uni to discuss solutions; it doesn't actually say it is going into Vic Uni. Yeah.

Matt presented the mathematical expression that he came up with. He stated that, even though it was a basic solution, it provided a useful approach.

Matt: Have a look at the basic idea of the electrical buttons and it's really basic.

Claire: Yeah?

Matt: That's what I came up with. Three basic ones, but this isn't like incorporating doors or anything, but I think it can be done like that. I don't know there is probably, might be errors in it.

Bruce: Is it like they all need to be 1 for the door to close to start"?

Matt: No they are 0's. (Starts to explain his interpretation of the input and output signals in the lift and how he had come up with the equations).

Claire summarised all the ideas and restated them to seek the approval of the team members. She proposed the use of pneumatic vacuum lift design for low cost and superior ride quality.

8.3.2 Team B

Ali and Khadir had studied in the same PBL team during the entire first year. Jeff and Theo had been in different teams. The personal and academic backgrounds of these students are as described in Chapter 5. Khadir and Ali were Africans. They had both attended school in their country of origin and in Australia. Jeff was born overseas in South Africa but had attended school in New Zealand and in Australia. Theo was an Australian-born student of European ethnicity. All of these students had entered tertiary education directly from secondary education.

Jeff and Theo arrived on time for the meeting. However, we waited for almost 15 minutes before Ali and Khadir arrived, who apologised for being late. The atmosphere in the team was relaxed but silent. None of the team members participated in social chat. When the students were asked to introduce themselves to each other, everyone announced their names and again became silent.

Once the problem documentation was delivered, students hurriedly flipped through the pages. The picture of the lift seemed to attract their attention more than the description of the problem. In less than a minute after the problem was delivered, Jeff asked Khadir and Ali what they thought about the problem. Khadir suggested the use of a counter design to count the floors, which he had learnt in the first year electrical engineering course and Khadir was also keen to apply what he had learnt earlier.

> Jeff asked Ali and Khadir: What you guys think about the problem?
>
> Khadir: We need some sort of a counter.

Even though the expectations of the activity and the timeline were made explicit to the team, they deviated from this plan as soon as they received the problem. Before reading the problem and interpreting its requirements and without gaining a complete understanding of the problem, the tasks and the expected outcomes, they started offering possible solutions.

> Jeff: Counter? As in target counter or people counter?
>
> Khadir: Counter to counting the floors.

[Ali murmurs something to himself].

Theo: So, what we needed is a lift, it's generally it is sitting down, not doing anything and just waits, and then a person would press a button, they will say whether they are going up or going down and the lift will say that is either the floor above or floor below or the same floor, two floors above or two floors below.

This approach created confusion within the team. Realising that the students were having difficulties in making sense of the problem, I interrupted and asked the team to take a more considered approach to the problem.

Researcher: Alright, everyone. Please listen. I would like you to stop discussing possible solutions. Like I said, before you start to discuss, find out what the problem is first, look at what is expected. The tasks are in page 2 of the problem document. Then you can talk about what is required, what do you need to do to get what is required.

Very quickly, Theo started to read out the problem, using his body to non-verbally demonstrate his perception of the problem. He seemed eager and directed the team's attention to his conversation.

Theo: So it responds when a person presses a button. Until then it doesn't do anything. Since we are only messing around with three floors, it is enough to say either we have a bottom floor or a top floor. Then the person in the lift, the lift will know whether it is going up or going down depending on the direction of the button you are pressing. There is a diagram of that here.

But because he continuously engaged in describing the problem to other team members, he left them with no time to read the problem or take up any role during the first ten minutes of the activity. From the beginning of the activity, Ali and Khadir remained passive.

Theo: It says here that the lift can be called with the intention of either going up or down. So that's with the person's button press and then when that happens, it decided the mode whether it is going up or down. So I think it just depends on …

(Theo rotates his arms up and down to indicate the movement of lift. Uses gesture to express his perception. Ali and Khadir were flicking through the problem document while Theo was explaining).

Ali: Otherwise the lift it is passive if none of the buttons are pressed.

Theo interrupted and reflected on his experience while travelling in a lift. He started to explain the ways lifts normally operated in office blocks, including the ways they may respond to requests, and pulled all the points together in order to visualise the problem.

> Theo: Most places that I have been in the city, that is an office block with these many floors say down St Kilda Road, its generally they are not that busy. You turn up during the day, there is nobody? It is because the whole business is on one floor. I am just assuming this. But if it is say for a shopping centre or a mall; then it will be busy.

Soon the team started to discuss in which floor they need to position the lift for energy saving as it only operated between three floors. However, no one in the team discussed their learning needs or the information required for solving the problem, e.g., the lift mechanism, the sensors or the actuators that were required to control the lift operation. It was evident that the team was unlikely to progress or identify learning needs without facilitation.

Jeff confused himself and others about the lift's operating sequence between floors. He struggled to understand how the lift behaved when requests were made from inside the lift and outside the lift. Theo and Jeff continued chatting about the traffic in the lift and the control mechanism involved in operating the lift. At times they discussed technical issues without knowing the significance of this information and its implementation for this problem. Theo drew on examples from his past experiences and questioned his knowledge and other team members' knowledge on safety issues concerned with the lift's operation.

> Theo: Since it is only three floors it does not really matter where the lift stays as a default. So you can just say, the floor that the last person got off, it just stays there. Because it is only three floors.
>
> Ali: Otherwise if there are heaps of floors then we have to keep it in the middle or somewhere.
>
> Jeff: So if the person pushes the button to say up, it will rock down all the way to the floors below there. Say if you are in level 2 and you want to go up one level to 3 and if you press the button to go to level 1, will it actually go to level 1, or will it wait there for another response.
>
> (It appeared that Jeff was struggling to explain his thoughts to his team members. He realised his team members hadn't understood his question only when Ali interrupted. He appeared to confuse his team members with his question and the discussion wasn't going any further).
>
> Ali: What do you mean?

> Jeff: If you are outside in level 2 and want to go up and press the up button from outside for the lift to come to your floor and take you up. Once you board the lift, you then press level 1 instead of 3. If in that situation, will the lift lock out or will it go up to 3 and then come down or will it stay there.

At this stage, the students were directed by the researcher to read the problem again carefully to develop an understanding of it and to start using the resources to find relevant information.

> Researcher: Guys, I mentioned at the beginning that the first ten mins is for you to read and understand the problem. Now, what do you know about the problem? What is required of you and what are your tasks? Can someone tell me what you have understood from the sheet that I gave you about the problem? I will also get you to start using the resources; the books and the internet to find information that could help you to solve this problem.

Ali acknowledged the comment and referred back to the problem and pointed out that there were other things such as the reliability, cost saving and better ride quality that needed to be considered. Ali, Khadir and Jeff flipped through a few books that were provided. Soon the team members became involved in individual learning processes. Theo quickly got hold of one of the two computers provided and started to search the Internet for information. As he found new information, he also kept passing the information to other team members.

> Theo: Well, it turns out there is a website here it's mentioned, I just read, they said they were designing, a three floor to ceiling glass walled hydraulic elevator.
>
> Jeff: Glass walled?
>
> Theo: So it is like the one in building M (a building at the students' university).
>
> Theo: Oh, it says these ones travel a 100 feet which is actually double the height of a conventional hydraulic elevator. So I am assuming that the normal one is only 50 feet. This one can carry 100 passengers. Oh this one is really big.

Jeff occasionally threw in some seemingly unconnected probing questions such as what type of lift the team was planning to select, how many passengers they needed to consider while designing the lift and what purpose the lift was going to serve. It was evident that his questions were aimed at stimulating discussion and critical thinking. Theo started to respond to Jeff's questions.

> Jeff: I just have a question about fire; will the lifts operate during fire? Or will the lift shut down and people will use stairs.

Theo: I think it is supposed to shut down.

Jeff: Is it?

Theo: I am assuming it will shut down and people will have to use stairs.

Jeff: If the fire alarm goes off, it just switches off maybe? Is it only the fire alarm or is it any alarm?

Theo: I know some building, when there is a fire in an office block, they have got these fire proof doors that actually just shut and to actually stop the fire spreading into the actual office block so everyone will just sit and wait. But I think the elevator is supposed to stop or maybe go all the way down to the bottom floor, that's probably safer.

Ali and Khadir did not seem to bother with Jeff's questions or Theo's responses. Jeff's probing questions were either misunderstood by other team members or were ignored.

Jeff tried to pull together the disjointed ideas that were contributed by Theo. He referred back to the problem and discussed key tasks. He tried to include Ali and Khadir in conversation but had limited success with either of these strategies. On many occasions, Theo restored individual learning processes soon after contributing surface-level ideas.

Theo: It is a pretty big design.

Jeff: It is very costly then, hey?

Theo: This one, yes.

Jeff: It is better to then go for cable?

Theo: They are saying, sorry, there is this other website, the normal cable one there is a special stop mechanism that will stop the lift from slipping down to the bottom.

Jeff: Oh there is the other cable to protect? Is it or? Hey guys, how about this diagram? Do we have to use huge springs at the bottom, like as a safety device to cushion it if there was, like to stop the cable if something goes wrong and falls, just to cushion it?

Ali: Down at the bottom? Yeah.

Jeff: Yeah.

Theo: I think that's the idea.

In order to get the team back on track, the researcher asked some questions and directed their attention to the tasks.

Researcher: Have you come up with what type of lift or what different kinds of lift you might want to look at?

This question prompted Jeff to recommend the use of hydraulics as the lift under consideration was to be used only for serving traffic between three floors. Theo agreed with this suggestion as his research about hydraulic lifts was consistent with Jeff's research. They both started to discuss hydraulic lifts, the cost involved and the materials used for construction.

> Theo: OK, it says that, for the standards that universities are using, it says that any two to six floor structure with a maximum height of 60 feet needs an in-ground hydraulic or gear traction and anything above seven floors just gear traction. So we have got an option of either one.
>
> Jeff: If it is hydraulic, I mean you can meet different distances, if it is hydraulic and fixed to ground, it can be easy to maintain, you don't have to go to the side of the lift and -
>
> Theo: With the gear traction, you can have certain number of tractions per gear. But I am with the hydraulic, except for the fact that the expandability of that lift is only to 60 feet.
>
> Jeff: So you can't actually build on it.
>
> Theo: No, it can't go any higher than that.
>
> Jeff: So if we have more levels?
>
> Theo: If we have more levels then we need to have another lift that goes from 6th floor.
>
> Jeff: Could you find out costs for me?

Theo later recommended the use of magnets that he had come across while searching for types of lifts on the Internet. Jeff was excited by this idea and declared it "brilliant".

> Researcher: There is a twist in the problem. Look at the tasks in page 2 of the document. You are required to come up with a possible innovative idea.
>
> Theo: Magnets. That's a bad idea.
>
> Researcher: Why is it a bad idea?
>
> Jeff: It's brilliant.
>
> Theo: Wouldn't it take a lot of magnets? Yeah, like the bullet trains. Because, I found in this website, it says here that, like once they had an entire building in magnets. It was like 50 feet off the ground; they had it bounce like up and down.

Soon, Theo started to explain the working of magnetic lifts to the team and tried to get others to go along with his ideas. He took pleasure in communicating his ideas and used gestures to illustrate them. In the following excerpt from the video transcript, it can be noticed that Theo pointed out that the team might have to think about cost effectiveness, considering the safety issues associated with the operation of this type of lift. On many occasions he read directly from the website that he had found on the internet.

> Theo: … I don’t know if there are any cheaper options. But it would mean you wouldn’t have to worry about, the only, I would suggest we need to look at safety and things, like if the lift fell it will lock the lift and hold it up, just in case the power went off. Because during a rain or a blackout the building’s got a big problem. So we need to have some kind of backup generators, you’ve got to work out if that is cost effective or not. The control room wouldn’t have to be that big. They are probably big enough to hold the generator, I assume. It wouldn’t need much maintenance. It is a good idea.
>
> Jeff: What about having coal, like the engine at the top and you know hydraulic at the bottom or you know magnets each one, you know the actual engine thing to the combs on the sides, like if it is there on the sides, it pulls itself up and down.
>
> Theo: You could do that.
>
> Jeff: Or, like this on sides and pulls itself up. Will that work or is it too large?
>
> Theo: Nah, it will work. You need to have power to the lift.
>
> Jeff: Power to …
>
> Theo: To the actual cable, so you have a cable and then …
>
> Jeff: So the cable will protect itself up?
>
> Theo: Yes, Yeah. You could do that, it will work.

While Theo easily managed to get Jeff to work with him, he ignored the presence of Ali and Khadir. He explained the way the bullet train worked and related that to the lift. He also quoted that Toshiba was releasing its model in 2008. Jeff suggested that they could use an integrated circuit chip to control the lift. As Theo continued to explain the concept of the magnetic lift, Ali interrupted to say that he could not understand anything. Theo ignored this comment and continued to converse with Jeff. In the following example from the combined video transcript and observation field notes, Theo clearly ignores Ali’s questions.

> Theo: We could have magnets on the lift and along the side, and then you constantly change polarity from outside so they are constantly pulling the magnet up or pushing it and then you can actually do the same thing on the way down. So we are not going to turn on a series of magnets, were going to change the current running through.
>
> Ali: What are we going to use to order it like to some …?
>
> Theo: Hey?
>
> Ali: To tell the lift like something.
>
> (Theo removes eye contact from Ali and starts talking to Jeff).

Theo: The controller then sort of runs, how the electricity is going to be running through, I am assuming.

Jeff: You know the programming that you were saying, if we did that, you just pick some numbers and say, lift is X long, that means it will make it a little bit or something. If we built the lift like completely digital then we can't modify the lift is that right? So we have to go for programming. Would that be enough to make each magnet will have the brain, the digital programming chip, as many magnets it has, as many ups it should have?

Theo: Well depending on how the coils work I think you could just have alternating input and outputs so it's just doing like a …

Jeff: Oh, so it acts like an inverting gate.

(Khadir was scribbling something in the problem document. When I took a closer look, I realised he was doodling pictures of flowers and cars.)

Jeff: Inverting gate and it continuously swaps.

Theo: Yes it swaps. So all you are doing is sending a high and a low to different parts.

Ali: I can't understand this physics thing.

Theo: Oh yeah you need some kind of damping as well. We can also have an inbuilt metal detector. If someone walks with a gun, beep.

Jeff: With the problem, would we use just magnets or with springs or if the lift goes down it bounces up and down and so on?

Theo ignored any questions from Ali and Khadir. It is possible that Ali and Khadir felt that they were not included in the team and hence distanced themselves even more from the team. They both became completely silent and avoided any eye contact with the other two team members. At one stage, Ali and Khadir repositioned themselves facing one another and disengaged from the discussion.

At the end of time for this activity when the team members were asked to present a proposal, Theo suggested a magnetic lift as the best solution as he found it fascinating and a novel idea. He claimed that it was the best solution as it fitted most of the criteria in the problem documentation.

Theo: Well, we have figured out an advanced lift controller system that brings a significant technological benefit with in terms of the ride quality. I am not too sure if it is cost efficient or reliable compared to another type of lift. But it is on; provided the safety mechanisms of this lift is adequate enough to stop from falling then it will probably tick off the reliability as well. We use magnetic force for movement; this translates into a quieter, smoother and more comfortable ride no matter the direction.

Jeff: Oh.

> Theo: Can travel up to 984 feet in a minute, a number that is relatively slow when compared to standard lifts. So, it is a slower ride, but it is much, much, much more comfortable. So that ticks off all the requirements.

It was very clear that the decision was not unanimous as Theo pushed Jeff to go along with his thoughts. Theo also blocked Jeff's communication and once teased him for a question that he asked. While Jeff seemed unaffected by Theo's approach in critiquing his disciplinary knowledge, Theo took pride in the new knowledge that he had gained from the Internet. As the members of the team did not question the validity of the perceived information, it was easy for Theo to copy the ideas from Internet websites. The team members did not have a common understanding because they had neither shared the information retrieved nor used the information collaboratively in solving the problem.

8.4 Findings

From the analysis of this problem-solving activity, it was found that the two student teams approached problem-solving in PBL quite differently. In interpreting these findings, it is important to remember that this problem-solving activity was not part of their course. It was, in a sense, a contrived activity in that it was conducted over a one hour period only and was not formally assessed in any way. These factors may well have had an impact on the attitudes of the students to the activity and their responses and behaviour while taking part.

The students were also asked to reflect on their performance in the problem-solving activity at a later date. They stated that while the problem in the activity was similar to those experienced in their course, the information provided for the activity was generally clearer than that provided in the course.

8.4.1 Approaches to learning as a team in PBL

Students in Team A approached problem-solving by assuming responsible roles and identifying their individual learning needs. Claire in Team A briskly organised the team's initial ideas and assigned herself to the task of information research. Other team members also assumed roles within the team and very quickly agreed on the process to be followed. The members of Team A efficiently worked out the group processes by effectively communicating with each other, and then worked together through the problem-solving process.

Throughout the activity, all members in Team A remained consistent in their roles till the end of the problem. This could be because they adopted roles that they were comfortable with or because they rapidly managed to adapt to new roles not previously experienced in the PBL learning setting. Phillip initially displayed introverted behaviour and anxiety, but after gaining confidence he was also drawn into working with his team and his idea, derived from a television cartoon, was eventually adopted by the team. They also appeared to identify the common group learning needs and hence suggested a solution after mutual agreement.

Students in Team B, on the other hand, approached problem-solving by immediately suggesting possible solutions. They did not take up consistent roles and therefore struggled to identify a group process that would engage and involve all the team members. They clearly struggled to apply the relevant generic skills. While Jeff tried to be inclusive and sought Khadir and Ali's opinions at times, Theo, who found himself in a leadership role, alienated Ali and Khadir by consciously ignoring them. Theo appeared to lack confidence, did not understand or know how to interpret new information collected by his team members and therefore could not apply it in this problem-solving situation. His perception of the unplanned leadership role may possibly have influenced his behaviour.

Ali and Khadir chose to remain passive and disengaged for almost three quarters of the duration of the activity. When Ali contributed to the discussion and tried to explore the new ideas, he was interrupted, with scant consideration of his right to participate. The passive behaviour exhibited by Ali and Khadir may be attributed to their difficulties in communication, their racial differences and/or their different understanding of the norms and values shared by Australian students, their sense of racial discrimination by other members of the group, or their lack of interest in participating in the problem-solving activity.

In spite of completing 50% of one year's coursework study load in PBL setting, and at least one member of this group having effectively led a team that adopted a collaborative learning culture throughout the year, the students in Team B struggled to apply the lessons they were supposed to have learned about organising effective group processes. With facilitation from the researcher, they eventually adopted an effective problem-solving process.

8.4.2 Disciplinary and cross-disciplinary knowledge

Students in Team A constantly validated their developing understanding with the team and reflected on the problem as well as on their newly gained knowledge. Matt interrupted the problem-solving process with his jokes and comments on some occasions. However, his other team members maintained their focus on the task at hand. They displayed an awareness of cross-disciplinary knowledge when they discussed the use of cable lifts and hydraulic lifts. Matt integrated his prior mathematics experience in solving the lift controller problem. He suggested a "basic" design for the lift's operation by reducing the problem to a set of equations and solved them by using Boolean algebra, truth table and finite state machine approaches. This indicated Matt's application of digital electronics knowledge that he had gained during the first year of his course.

On the other hand, the students in Team B struggled to understand the tasks and the requirements of the problem. They started to suggest possible solutions as soon as they received the problem documentation. At times they discussed technical issues without identifying the relevance of that information and its relevance to this problem. Jeff asked Ali and Khadir for their opinion about the problem. As Ali and Khadir declined to contribute to the conversation or use the technical language related to the subject of the problem, it appeared that their passivity may have reflected deficiencies in disciplinary knowledge and skills.

8.4.3 Innovative thinking

Team A's innovative thinking capability was evident when Matt contributed a new idea, magnetic elevators, which was different from the idea the team was originally discussing. This innovative idea served as turning point in their problem-solving. Soon after this, Phillip contributed the idea of vacuum lift. This also provided evidence of the application of skills learnt from past experiences in an innovative way. Bruce and Claire retrieved detailed information about pneumatic vacuum lifts and the team eventually presented Phillip's idea as their suggested solution to the problem. So even though Phillip appeared to be only passively involved in the activity for much of the time, his contribution illustrated that he had been engaged in thinking about the problem.

The discussion between students in Team B remained at a surface level for the majority of the time and only after intervention by the researcher did they prepare themselves to apply newly gained information. After further intervention, they seemed to understand the problem and the tasks. But, by this time, more than half the time for the activity had elapsed. Theo discussed the option of a magnetic lift after conducting a search on the Internet. Jeff suggested using a software program to control the lift. Although these suggestions could be considered innovative, it was evident that Theo and Jeff neither conducted a thorough search nor clarified its application to the problem.

8.5 Summary and conclusion

This experiment was an attempt to identify how well the students were able to apply generic skills, use disciplinary and cross-disciplinary knowledge and think in an innovative way after the first year of a degree course that involved PBL. From this problem-solving activity, it is evident that students in each of these groups used their communication skills, disciplinary knowledge, innovative thinking and cross-disciplinary knowledge to some extent when solving the lift controller problem. It is likely that students' experience with problem-based learning in the first year degree course may have influenced the way these students approached problem-solving as a team and applied generic skills, cross-disciplinary knowledge and skills and innovative thinking.

Evidently, sudden shifts in conversations generated ideas, and provided scaffolding for innovative thinking. These ideas appeared to emerge from students' prior experience, for example the idea of vacuum lift from the television series "Futurama" in Team A and the idea of magnetic lift from the "Bullet train" in Team B. Hence, it is recommended that structuring problems that resonate with students' experiences is important for enabling innovation (Cornwall et al., 1976). While students in both the teams demonstrated openness to accepting innovative ideas, their prior experiences in problem-solving helped them to connect such innovative ideas to the lift controller problem.

Students in Team A successfully managed to establish a working relationship to effectively communicate, agree on group processes and problem-solving processes and thereby achieve successful group learning outcomes. The roles that students took in Team A helped them to understand quickly which ideas might work and which might not. They required little or no facilitation and applied their skills and knowledge efficiently. They constantly validated their ideas, information and findings by sharing them with their team members. They also engaged in discussing, arguing and negotiating with their team members. The behaviours of the students in this team and the processes they adopted indicated that they approached learning collaboratively. This could be compared to the collaborative learning culture adopted by Team 8 described in Chapter 6. As indicated in Chapter 6, Claire, Matt and Bruce were focussed on achieving high grades and belonged to teams that either adopted a finishing or performing culture during their course. While the findings of this simulated engineering situation still revealed that they still preferred to individualise their tasks, this situation without any formal assessment requirement encouraged them to adopt a collaborative learning culture by sharing information and their findings.

However the students in Team B did not take up consistent roles in the team. In spite of having worked for two semesters in PBL they failed to establish a working relationship in a new team setting and were unable to communicate effectively. They appeared to lack technical knowledge and skills, information processing and application skills, innovative and creative skills, and generic skills such as effective communication and team working skills. Hence, a great deal of facilitation was required to help them exercise their skills and engage them in team-work. The behaviours of the students in this team and the processes that they adopted while solving the lift controller problem can be compared to the finishing culture that was adopted by Teams 1, 2, and 3. In fact, all of the members except Jeff were members in Team 1, 2 or 3. Perhaps this explains why they adopted a finishing culture.

But, it was unclear why Jeff, the leader in Team 8 who perceived that his team's success would be his success and a pathway to obtain high grades in PBL, changed his behaviour and let this team adopt a finishing culture in this situation. As this was a contrived activity and was conducted only for a short period of time, it is possible that Jeff did not see the need to encourage a collaborative learning culture. It is also possible that Jeff and other students may have altered their behaviour and may have not cared because they were informed that this activity did not count for assessment.

In conclusion, this experiment provided an insight into how students respond to a different group problem-solving situation after one year of study in problem-based mode. It was not surprising to see one team adopting a collaborative learning culture while the other team adopted a finishing culture. This implied that there could be several contributing factors that motivate PBL teams to adopt a collaborative learning culture. Some of these factors were identified in Chapter 6. The findings of the group problem-solving activity also indicate similar factors that promote a collaborative learning culture in PBL teams. These factors include group composition, establishing respect within the team, team leadership, effective group processes fostered through facilitation; as well as the skills and processes articulated (or not) in the curriculum. These findings will be discussed further along with all other findings presented in Chapter 5, 6 and 7, in the final chapter focusing on the identification of the key elements that contribute to the success of PBL teams.

Chapter 9

Discussion and conclusions

9.1 Introduction

This study set out to explore the life of students in problem-based learning (PBL) teams from the point of view of students and to theorise the key characteristics that underlie the creation of various learning cultures in an engineering PBL setting. In particular, this study investigated the experiences of first year engineering students to a newly implemented engineering PBL curriculum at Victoria University; its effects on their individual approaches to learning, their approaches to learning in teams and their learning outcomes. In the first year of the curriculum change in this PBL setting, student approaches to learning and their learning outcomes were interpreted by analysing the ways in which these students approached, controlled, regulated and directed their learning individually and as a team in PBL. As students in this PBL setting were from diverse school and work experiences and from diverse linguistic and ethnic backgrounds it was expected that the nature of learning cultures adopted by student teams would reflect their heterogeneity. Another goal of this study was to discern whether this PBL setting lived up to the general claims made about the advantages of using PBL by examining some important learning outcomes, including those relating to disciplinary and cross-disciplinary knowledge and to innovative thinking.

Such a diverse cohort is not new for Australian higher education institutions. However, little research had been conducted to study the effectiveness of the learning that happens in PBL teams in engineering, particularly by using naturalistic approaches to investigate student learning interactions. At the time of commencement of the current study, research on the ways in which students approach, control, regulate and direct their learning as a team in a multicultural PBL setting was limited. Evensen, Salisbury-Glennon and Glenn (2001) and Hmelo-Silver (2004) were notable exceptions. This gap in the literature prompted the need for more descriptive, naturalistic approaches to theorise self-regulation among autonomous learners and the knowledge that is situated and gained by being part of an activity, context or culture, which was often ignored (Brown et al., 1989; Evensen & Hmelo, 2000; Evensen et al., 2001).

Hence, ethnographic observations were used as the main method for data collection in this study. These were supplemented with semi-structured interviews, student portfolios (student work samples) and a group problem-solving activity for a small random sample of students in the cohort. Data were analysed using qualitative data analysis methods. There were three steps in data analysis: description, analysis and interpretation. Data analysis began with the description phase, in which observation field notes were summarised and audio and video recordings were transcribed. This was followed by the analysis phase, in which transcripts were dissected by means of coding both manually and using NVivo software application (Bazeley, 2007). Codes were clustered and categorised. In this phase, a combined description (narrative) was also generated from the observation transcripts, field notes, interview transcripts and the portfolios. Narratives of twelve students and eight teams are presented in Chapter 5 and 6 respectively. In the interpretation phase, cross-case analysis was performed to compare and analyse the similar patterns that emerged from individuals as well as from teams using simple diagrams and matrices. Diagrams and matrices helped organise data efficiently and to focus thinking. Some of the themes and sub-themes displayed during analysis often became the chapter subheading in this dissertation.

During the course of analysis many factors that influenced the creation of a successful PBL team started to become obvious. It was found that the success of PBL teams in this setting was mainly influenced by the attitudes, behaviour and learning approaches of the student members in that team. Other factors such as teacher practices, location, course design and implementation, resources, student understanding of the expected outcomes and assessment methods also seemed to exert influence on what and how students learnt in this PBL setting.

Three different learning cultures emerged from the analysis of the common characteristics that influenced student learning in the eight PBL teams that were the focus of this study. They were the finishing culture, the performing culture and the collaborative learning culture. These learning cultures represent a hierarchy in terms of their complexity as well as success.

Students in teams that adopted a finishing culture focused on finishing the problems and project with minimal effort. Most students only attended supervised team meetings. There was little evidence of good communication or mutual respect. Team leaders allocated tasks to team members and directed them to work individually. Most students used a surface approach to learning. As a result, teams that adopted a finishing culture were least successful in learning in this PBL setting. The knowledge of most students in teams adopting this culture was comparable to the pre-structural or uni-structural levels of knowledge as defined by Biggs and Collis (1982).

Students in teams that adopted a performing culture focussed on achieving high grades. Hence, they focussed on a comprehensive solution to the problem or the project and preparing impressive individual portfolios. Students engaged in discussing problems and brainstorming ideas but often did not share the work equitably. Students who desired high grades used deep or achieving approaches to learning, but encouraged passivity in other members who used a surface learning approach. The knowledge of some members was comparable to the multi-structural level of knowledge as defined by Biggs and Collis (1982). Teams adopting a performing culture were more successful than the teams adopting a finishing culture in terms of their problem or project solution. However, there were quite unsuccessful in terms of supporting the learning of all members.

Students in the team that consistently adopted a collaborative learning culture focussed on learning collaboratively as a team and accumulating evidence of learning for individual portfolios. Excellent communication and a high level of participation during both supervised and unsupervised team meeting were evident in this team. Students valued team-work and mutually respected each other. The team leader ensured collaborative work on all aspects of the problems or project. Team members focused on finding more than one solution to each problem. This team was most successful in supporting the learning of its members. Most students in this team used a deep approach to learning. The knowledge of some students in this team was comparable to the relational level of knowledge as defined by Biggs and Collis (1982). The collaborative learning culture appeared to enable students develop both disciplinary and cross-disciplinary knowledge and innovative thinking skills.

The findings of this study indicate that the attitudes, behaviours and learning approaches of students and the learning cultures adopted by teams in this PBL setting were situationally determined (Brown et al., 1989). The important question that became apparent during analysis of the data was what is needed to make PBL teams successful. The findings from the study along with tentative theories regarding this question will be discussed in this chapter by considering each factor that contributed to making PBL teams successful.

9.2 Making PBL teams successful

The literature suggested that PBL is a group learning environment that involves a radical change in the way students learn and the role that academic staff play in facilitating learning (Savin-Baden, 2003; D. R. Woods, 1996). The PBL approach claims to build extended technological and social understandings as it offers a context for development of autonomous learners (Biggs & Tang, 2007). It has an emphasis on encouraging collective and individual learning motivation and decision-making behaviours (Hmelo-Silver, 2004).

Researchers have indicated that learning in learner-centred settings is strongly influenced by several factors. While the attitudes, behaviour and learning approaches of students mainly influence what is being learnt in classrooms, researchers have reported that factors such as supervisor practices, course design and implementation and assessment may have significant effects on student learning in PBL (Hmelo-Silver, 2004; Savin-Baden & Major, 2004; Weimer, 2002). Such studies present a rather positive view of the process of learning that happens in a PBL setting.

The findings of such studies therefore appear promising for institutions that wish to adopt a particular PBL model practiced at one institution or to apply a similar model at their institution (Stojcevski & Veljanovski, 2007). However, the deliberation that is required with respect to designing, implementing and facilitating a course using PBL is often underestimated (Savin-Baden, 2003; Savin-Baden & Major, 2004). While the current study did not set out to paint a negative picture of PBL, the findings of this study emphasise that there are always opportunities for enhancing the quality of learning that happens in PBL classrooms.

Akin to engineering PBL settings in Australia and overseas, the setting that was created for students at Victoria University aimed at producing engineers who have a good balance between technical skills and generic skills (Victoria University, 2005). Despite the fact that team-work is fundamental in any PBL setting, the findings presented in Chapter 6 suggest that most student teams struggled to understand the processes involved in learning as a team in this PBL setting. In addition, the findings suggested that most teams struggled to understand the problem, understand the expected learning outcomes, identify their learning needs, identify effective group processes, adopt self-directed and group learning strategies, develop an understanding of possible solutions and/or apply newly gained knowledge to solve the problems and the project set for them in the PBL subjects. These findings reported in Chapters 5, 6 and 7 were triangulated through the group problem-solving activity reported in Chapter 8.

The evidence of the learning approaches of individual students presented in Chapter 5 and the way they approached learning as a team presented in Chapter 6 indicate that most students in this PBL setting were inclined towards working individually on their preferred tasks within their teams. It is likely that different understandings of team-work and different understanding of learning in a PBL setting resulted in the three different learning cultures that were identified in this study. It is also likely that these learning cultures in PBL teams emerged as a result of the diverse personal characteristics of students, team characteristics and teaching practices.

Teams that focussed on finishing each problem or project in PBL were identified as adopting a finishing culture in this study. Students in teams that adopted a finishing culture were extrinsically motivated and therefore engaged in learning as a team only to pass with minimal effort. Most students in these teams assumed relatively passive roles and they were inclined towards finishing the problems or project by solving them as individuals. Biggs (2003) identified such students as adopting a surface approach to learning. These students did not tend to see a connection between the problem and the stated learning outcomes and appeared to believe that the expected outcome in PBL was to “solve” the problem. It was found that, when the number of students who adopted a surface learning approach outnumbered the students who adopted other approaches within a team, the team appeared to adopt a finishing culture. This finding is analogous to Belbin's model of team roles, in which he emphasised that "if team members have similar weakness, the team as a whole may tend to have that weakness" (Belbin, 2007).

Teams that not only focussed on finishing each problem and project but also focussed on maximising the grades their members obtained were identified as adopting a performing culture in this study. As some students in these teams were particularly concerned about their own individual achievement, they encouraged passivity more often, and competition less often, of other team members. Students in these teams presented a mosaic of individual contributions as evidence for team-work. In other words, they understood that PBL required team-work but were prepared to use the assessment system to maximise their chances of obtaining high grades in PBL. Previous research suggests that such students are advanced game players and set their own rules for playing the problem or project game in PBL (Gabb, 1981). Biggs and Moore (1993) identified such students as adopting an achieving approach.

On the other hand, the single team that consistently focussed on learning and collecting evidence for their portfolio by addressing the requirements of the unit learning outcomes rather than focusing on completing the problem was identified as adopting a collaborative learning culture in this study. Students in this team engaged in an increasing amount of face-to-face contact. They valued team-work, mutually respected each other and shared their ideas and findings in each problem and the project. Biggs (2003) identified such students as using a deep approach to learning.

This team is of particular interest here as the strategies that the students in this team adopted clearly indicated the factors that were intertwined in making a PBL team successful. But evidently, even this team did not adopt a collaborative approach automatically. It is recalled here that the leader of this team, Jeff was in fact motivated to achieve high grades. But he changed his approach to learning in PBL when his supervisor told him that his team's success was his success and therefore a pathway to obtain high grades in PBL was to make a successful team.

This meant that the supervisor of this team played a significant role in managing and directing student learning and shaping the learning culture adopted by this team in this PBL setting. Paradoxically, it appears that Jeff advocated and nurtured a collaborative learning culture at least in part because he believed that this would maximise his personal grade. Thus, his achieving approach as an individual led ultimately to a collaborative learning culture in the team.

In Chapter 6, the key attributes that influenced the learning cultures adopted by student teams were presented in Table 6.3. These attributes were membership, group processes, leadership, individual approaches to learning and approaches to learning as a team in PBL. The attributes presented in Table 6.3 were analysed for a number of dimensions including the personal characteristics of students, team characteristics, teaching practices and course documents.

From this analysis, a complex mix of interacting elements started to become evident and appeared to contribute to the relative success of PBL teams. It was evident that the interactions of these factors in each team played an important role in shaping the learning culture adopted by their team and exerted influence on their learning in this engineering PBL setting. The following Figure 9.1 represents the interaction of the elements that were identified to promote collaborative learning culture in PBL this PBL setting.

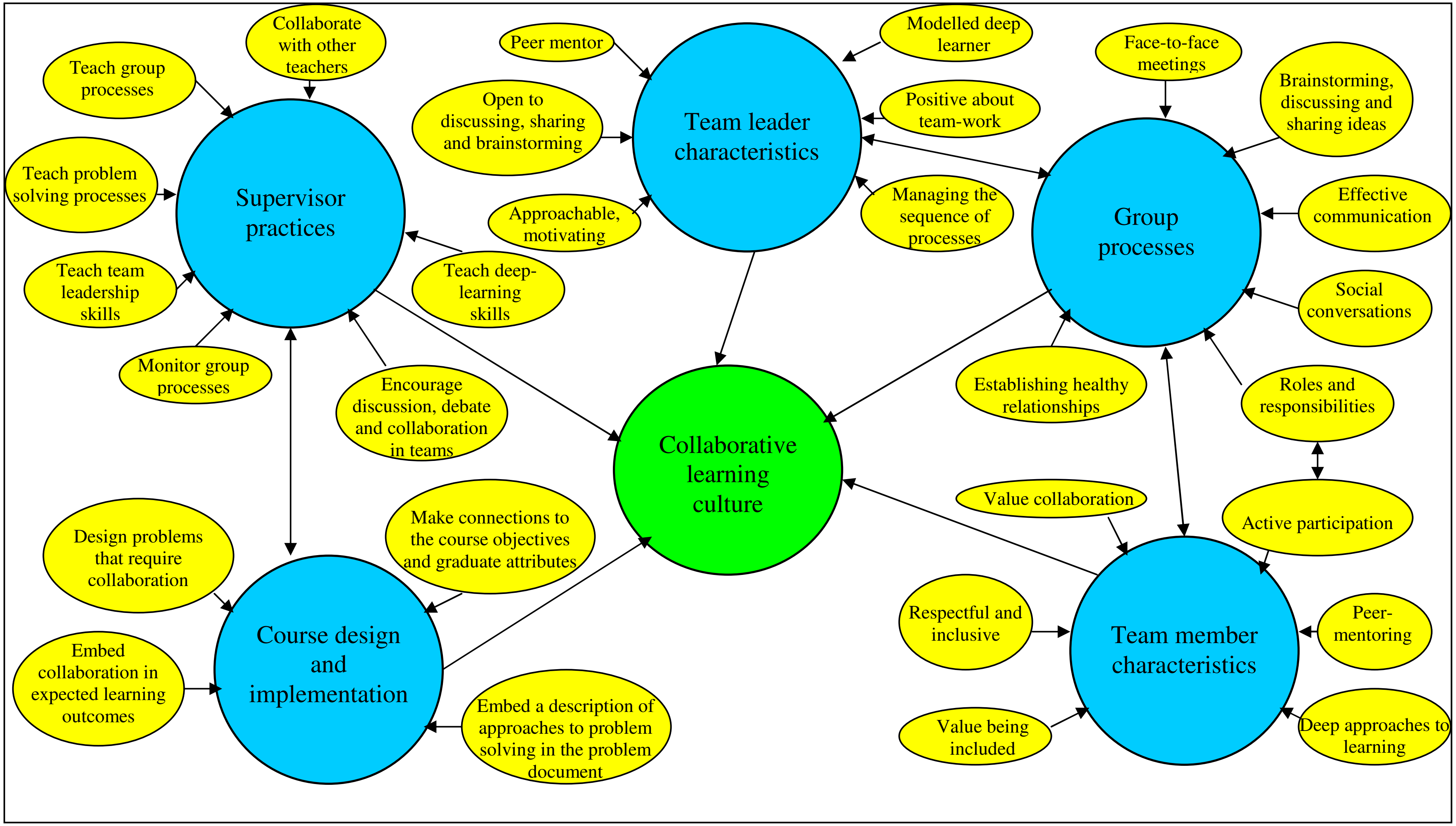


Figure 9.1 Elements that promote collaborative learning culture in PBL

9.2.1 Student and team characteristics

Reflecting on the initial conversations that I had with the student participants in this study, I recall that most students, irrespective of their background, expressed a desire to obtain a highly paid job at the end of their course. This motivation may have influenced their thinking about what to expect in the course of gaining a professional qualification. PBL in this setting was a new experience for students as well as for most supervisors. It called for a change in student perspectives of learning and functioning at university even though for most students it was their first experience of tertiary education.

Students in this PBL setting were not similar to each other; they had different school and work experiences, different capabilities, different learning needs and different perceptions. The research literature suggests that students do not simply learn subject content. They also learn about people, contexts, likes and dislikes and more importantly about themselves in a PBL setting (Savin-Baden, 2000). According to Savin-Baden (2000), the personal characteristics of students, including their attitudes and behaviours and their beliefs about the norms and expectations while being part of a PBL team interact and affect one another's learning. It is therefore possible a successful PBL team could have meant different things for different students and different teams. Perhaps, their different understandings of what it means to be a successful PBL team may have resulted in the three different learning cultures in this setting, where some teams focussed on finishing, other teams focussed on performing and one team focussed on collaborative learning.

According to the theory of social interdependence, positive interdependence; that is co-operation, exists when individuals perceive that they can reach their goals if and only if the other individuals with whom they are cooperatively linked also reach their goals. Participants, therefore, promote each other's efforts to achieve the goals (D. W. Johnson & Johnson, 2007). Negative interdependence, on the other hand, promotes competition and therefore participants obstruct each other's efforts to achieve the goals. Johnson and Johnson (2007) also argued that no interdependence results in a situation in which individuals perceive that they can reach their goal regardless of whether other individuals in the situation attain or do not attain their goals. This could be compared to the 'mindset of freeloaders' in PBL teams (for example, Team 2 and Team 4).

As discussed earlier in Chapter 6, students in the team that consistently adopted a collaborative learning approach (Team 8), demonstrated team-work characteristics that led to identifying factors that were intertwined in making a PBL team successful.

To recap: students in Team 8 were very positive about team-work. They were mutually inclusive and respectful of other team members and valued being included in the team. They actively participated in learning as a team, assumed various team roles and responsibilities, recognised the value of collaboration and identified effective group processes. They engaged in brainstorming, discussing, debating and sharing of ideas, findings and possible alternative solutions and thereby managed their group processes and problem-solving processes effectively. On some occasions they also engaged in peer-mentoring team members who had difficulty in understanding an idea or a task-solution. Students in this PBL team used deep approaches to learning and accumulated as much evidence as possible of their learning for their portfolio. They engaged in divergent thinking and reflection and produced alternative solutions to problems as a team. As their approach encouraged them to engage in an increasing amount of face-to-face meeting, it became obvious that deep learning approaches by members is an important factor in a team adopting a collaborative learning culture.

Another key factor that influenced Team 8 to adopt collaborative learning culture was the effectiveness of the leadership of their team leader and his motivation. The leadership characteristics that influenced this team's success included a positive attitude towards team-work, openness to group discussions, encouraging team members to discuss ideas and findings, managing group discussions, peer-mentoring, encouraging team members to share the workload, managing group processes, motivating team members to approach learning at a deep level, modelling a deep approach to learning and managing the overall sequence of processes in the team. These leadership characteristics indicate that the student who assumed the leadership role did not interpret it as power-oriented, despite the fact that he strongly influenced the approach taken by the team. Rather, as suggested in the literature, he took on various roles including:

- Manager – moderated group discussion, kept the team on task and made sure everyone worked well and had the opportunity to engage in learning
- Researcher – found resources and information that the team needed
- Encourager – valued other members' contributions
- Timekeeper – monitored time, set team deadlines, ensured no one was behind the schedule.
- Recorder – took notes of teams' discussion, prepared technical reports for the problems and project
- Checker – ensured all team members understood ideas, concepts, findings and solutions (Savin-Baden & Major, 2004).

Savin-Baden and Major (2004) argued that ideally, all team members should be given an opportunity to assume these roles to ensure that the team functions effectively. On the other hand, Belbin (2007) suggests that not everyone will act and think the same way and hence may not assume certain roles within the team. He also argued that when the mix and process is effective, team members may play to their strengths and recognise their weaknesses, in which case the resulting team-work will be robust and effective in decision-making and action. The difference between the work of Savin-Baden and Major and that of Belbin is that the former wrote about learning teams and the latter wrote about work teams. The aim of a learning team is to maximise the learning of team members and rotating roles may be consistent with this aim. On the other hand, the aim of a work team is usually to maximise the productivity of the team and role allocation may be determined by this aim.

During analysis, other factors that contributed to the success of this team were also identified. These include the approaches that the team adopted for working on the problems and the project. Previous research indicates that students develop flexible knowledge and effective problem-solving skills when the learning context demands the use of these skills. As students in this team discussed the problem as a team before identifying learning needs, it helped them activate relevant prior knowledge and facilitated the processing of new information. This finding was consistent with the findings of Hmelo-Silver (2004).

It is possible that students' preferred individual and shared learning styles influenced their team's outcome. A variety of reasons that may influence students' preferred learning styles are reported in the literature. Interdependence theory suggests that structured goal interdependence determines how individuals interact, which in turn determines their outcomes. Johnson and Johnson (2007) argued that positively structured goal interdependence results in:

- Promotive interaction – designed interaction between team members that promote assistance, openness, divergent thinking and feedback among team members;
- Individual accountability – holding students accountable for their work, contribution and progress within their teams;
- Group work and social skills – effective team functioning, establishing healthy relationships, trust-building, communication decision-making and conflict management;
- Group processing – group members reflect about how well achieved their goals during discussions and maintain effective working relationships.

On the other hand, experiential learning theory suggests that ideally learners should be guided through a learning spiral which allows them to experience, reflect, think and act (Kolb, 2007). PBL typically involves experiential learning. As suggested by a student participant in this team, PBL involves "getting the hands dirty" by engaging in problem-solving activities, which focus the learning experience of the learner.

Kolb proposed that experiential learning typically involves accommodating, diverging, assimilating and converging through active experimentation, abstract conceptualisation, reflective observation and concrete experience (Kolb, 2007). Evidently, the processes that students in the collaborative learning team used indicated that they preferred to learn collaboratively; that is, understanding the problems, identifying learning needs, brainstorming ideas, explaining ideas and findings and developing multiple products for each problem as a team.

It is possible that other teams may have used such strategies at times when they were not observed. But, from observation and from the findings presented in Chapter 7, it was evident that most students in this engineering PBL setting concentrated only on the disciplinary knowledge relevant to the particular task that they picked and completed for the team. They believed that their grades would reflect the quality of their task outcome and this not only appeared to influence their selection of tasks, but also indicated that they did not value sharing and negotiating their contributions with other members in their team. Evidently, students in these teams were focussed on individually solving their part of the problem and thereby maximising their chances of getting the grade they aspired to. As they did not approach learning collaboratively, it became obvious that these teams were not so successful in organising their group processes and their approaches to learning in PBL.

As discussed earlier, the group problem-solving activity was an attempt to validate these findings. The findings of the group problem-solving activity revealed that the student Jeff, who was very successful in building a successful PBL team during the first year course, did not even attempt this during the group problem-solving activity. The fact that this was a contrived activity conducted for a very short duration with students who had mostly not worked together before may have influenced the behaviour of the students. The students were also aware that they were not going to be assessed for their work in the activity. Hence, the simulated aspect may have altered the motivation of students engaged in the activity. It is possible that Jeff may have considered the activity a waste of his time and effort and hence he did not exhibit any of the leadership qualities that he demonstrated in his PBL team during the first year course. This may provide some confirmation that Jeff adopted an achieving approach to learning in his team, in that in this simulated activity with no assessment pressure he did not encourage a collaborative learning approach.

On the other hand, the other team undertaking the simulated activity managed to establish an effective social relationship. They communicated effectively, agreed on group processes and approaches to problem-solving, and thereby achieved successful group learning outcomes. This team appeared similar to some of the actual PBL teams that were on the verge of adopting a collaborative learning culture. Three student participants in this team mentioned that the lift controller problem that was designed for this activity was more open-ended, clear and allowed for divergent thinking and self-directed learning when compared to the problems and the project that they were given during their course. Although they thought that one hour was insufficient to solve the problem, they mentioned that the expected learning outcomes were realistic and directed their approaches to problem-solving.

The group problem-solving activity also revealed that students in both the teams were able to use their communication skills, disciplinary knowledge, innovative thinking and cross-disciplinary thinking to some extent when solving the lift controller problem. It is likely that students' experience with problem-based learning in the first year degree course influenced the way these students approached problem-solving as a team and applied generic skills, cross-disciplinary thinking and innovative thinking.

The overall findings of this study confirm that students can and do take a deep or surface approach to learning in PBL and that the approach they take is determined by the situations (Biggs, 2003; Brown et al., 1989; Lave & Wenger, 1991). This finding poses two challenges for supervisors: The first one is to convince students that their ability to work with others towards a successful outcome is a highly desirable capability in career terms. If developing team skills is an important learning outcome, grades should reflect this emphasis – a matter of alignment. The second challenge is to identify teams that are struggling with their group processes and their approaches to learning in PBL and to help them become successful.

9.2.2 Supervision

Previous research indicates that teaching and learning approaches such as PBL can provide extensive scaffolding to facilitate student learning (Hmelo-Silver, Duncan, & Chinn, 2007). In most of the PBL literature supervision is referred to as facilitation, defined as a subtle skill that requires teachers to identify how students learn and to use a range of methods to help them benefit from learning in a PBL setting. Facilitation includes meta-cognitive questioning that focuses student attention and eliciting causal explanations that present learners the opportunity to engage in knowledge construction (Hmelo-Silver, 2002; Savin-Baden, 2003).

Student participants in this study had diverse opinions about learning in a PBL setting. Most students were optimistic about learning engineering through PBL, yet they were also anxious and unsure. Most were definitely not confident or self-motivated learners to begin with, yet they aspired to obtain highly rewarding employment. Most students wanted their supervisors to tell them what to do mainly in terms of the PBL process but also in terms of technical content. Some students even complained to the Head of School about issues such as access to PBL studios, accountability of other students in their team, course implementation and supervision.

Although most students were positive about learning in this setting, they shared the opinion that supervision and course design and implementation were key factors that influenced their learning in this PBL setting. PBL typically involves placing students in small groups to learn through working on a problem as a team. It is therefore important for supervisors to understand the group structures that may form and how students may respond to those structures. Supervisors need to recognise the effects of diversity in teams and to help their students make the most of it. The findings here suggest that they need to provide students with a range of tools to make PBL teams work. In order to avoid teams adopting a finishing culture or a performing culture, supervisors need to encourage students to:

- develop a deep approach to learning by asking meta-cognitive questions and challenging their approaches and understandings;
- work and learn collaboratively as a team by valuing team-work, diversity within the team and modelling mutual respect within the team;
- adopt effective group strategies such as allocating team roles and responsibilities and discussing, debating, brainstorming and sharing ideas, findings and solutions.

If a PBL unit of study includes expected learning outcomes about developing team-work, learning and integrating knowledge from different disciplines and thinking innovatively while solving problems then it is important for supervisors to know what those outcomes really are and to help students understand how these outcomes may be achieved and documented.

It is often claimed that students' motivation, confidence and enthusiasm for learning are all adversely affected when teachers control the process through and by which they learn (Barnes, 2005; Savin-Baden, 2003; D. R. Woods, 1996). Evidently, in this PBL setting, most students felt that it was the responsibility of supervisors to regulate student learning. On the other hand, some students felt that their supervisors constrained the problem-solving process to the highest degree especially in Semester 2, instead of supporting or allowing them to regulate their own learning.

In this study some students in some teams were on the edge of using deep learning approaches, but they didn't quite get there because of their poor understanding of the expected learning outcomes in their PBL units. Some teams were also on the verge of adopting a collaborative approach to learning, but did not do so because some students in their team, and in some cases their supervisor could not see the value of collaborative learning.

If PBL is seen as a form of cognitive apprenticeship, the key functions of the PBL supervisor are modelling, scaffolding, coaching and fading (Collins, Brown, & Newman, 1989). Little evidence of supervisors modelling how an engineer thinks when confronted with a new problem was found in this study. The scaffolding provided for these students in their first experience of PBL was limited. Yet, Hmelo-Silver, Duncan and Chinn (2007) argued that scaffolding makes learning more manageable for students who engage in complex problem-solving situations, which would otherwise be beyond their capability (Wood, Bruner, & Ross, 1976). Coaching was evident and in some cases it was highly effective but it too was variable. Little evidence of fading was found. Indeed, there was some evidence of the level of supervisor intervention increasing as deadlines approached.

PBL is a designed process in which supervisors manage and guide student learning. Perhaps, when working with small groups of students or bringing students together to form small groups, PBL supervisors need to consider that a mixed-ability team or a mono-cultural team may not automatically adopt a collaborative learning culture. They also need to be aware that students do not automatically adopt a deep approach to learning. Therefore, supervisors should be able to recognise the attitudes, behaviour and learning approaches of students in teams and provide ongoing modelling, scaffolding and coaching by:

- modelling the way engineers think, especially at the beginning of the problem solving process;
- challenging student thinking with meta-cognitive questions that nurture deep approaches to learning, disciplinary and cross-disciplinary learning and creativity;
- providing an outline of the PBL process, monitoring the process and coaching when necessary;
- developing team leadership skills, including ensuring that all students are provided with an opportunity to lead the team and supporting them with coaching; and
- systematically and explicitly transferring responsibility for learning and knowledge sharing to students.

9.2.3 Course design and implementation

Savin-Baden (2003) has argued that there is growing concern that there is little focus on the experiences of learners and their learning when PBL courses are designed. Most PBL curriculum design focuses on processes, content and outcomes with an emphasis on different approaches to PBL and ways of implementing PBL (Barrows, 1986; Boud, 1985).

In Chapter 4, it was pointed out that PBL was used in this setting within a unit of study in which students were required to apply the knowledge that they gained from two lecture-based subjects during both Semester 1 and Semester 2. This indicated that PBL in this setting was used more as an instructional strategy in conjunction with lecture-based teaching (Conway & Little, 2000). An instructional strategy in this context is defined as a teaching approach that is used in addition to other teaching strategies.

Savin-Baden and Major (2004) noted that the current curricular practice in PBL is often complex. They characterised the model of teaching and learning in which PBL is mixed with other teaching strategies as a “hybrid model” (p. 36). They pointed out that in any PBL curriculum, problem scenarios should serve as the central component and lectures, seminars and laboratory exercise should feed into them. According to

Savin-Baden and Major (2004) designing a curriculum based on disciplinary content and then trying to make it problem-based usually ends up being a disaster both for students as well as for their supervisors.

The project in Semester 2 required student teams to develop a simulation of a traffic intersection before the end of Week 4. Supervisors verbally informed students that their teams should come up with a solution that has moving objects and changing light colours in the form of a simulation using the programming language Visual C. This introduced a constraint on acceptable solutions that made the problem considerably less open-ended than the project brief suggested. Clearly, the intention was to require students to develop the technical skills needed for simulating and testing using computer software applications. A traditionally taught subject that included programming was offered at the same time as the PBL subject but even basic programming was not taught in the initial weeks of the semester. The challenge for students without previous programming expertise was thus immense. It is possible that, after this experience, some students lost hope of learning engineering through PBL and adopted a surface approach just to complete the project and pass the PBL subject.

Many students shared an opinion that their supervisors constrained the project, controlled the steps in the problem-solving process but left them unsupported when they needed help to attain the expected learning outcomes. Particularly, students were concerned and confused when their supervisor decreased the complexity of the expected solution (product) when they realised that students could not achieve the target as a team. Students concluded from this that the activity was product-oriented, and developing a product became more important than learning. There was some confusion as to whether this product was a solution to the problem or an assessment portfolio. According to most students, their activity in their PBL teams was directed towards “solving” the problem and then towards “completing” the only assessment task, namely the portfolio. Not surprisingly, in second semester, their conception of PBL was strongly influenced by the grades they received in first semester. As they saw it, this indicated what PBL was really about – an impressive portfolio.

It was found that only highly intrinsically motivated learners adopted deep learning strategies. Students who wished to achieve high grades and perceived that at the end of the day all that mattered was their portfolio focussed on maximising that product. Support lectures and additional workshops that focussed on the portfolio worked well for these students but others by and large did not even bother to attend them. Absenteeism was common in most teams that adopted either a finishing or performing culture. But, if the problems and project design were synchronised with what was taught in the lecture-based subjects, it would have been possible to equip students to become independent inquirers, who may have seen learning and epistemology as flexible entities and may have learned that there are more ways of seeing things than from their own perspectives (Savin-Baden & Major, 2004).

Hence, rather than providing students with problems that expect them to learn isolated and unlinked facts and direct them to produce definitive outcomes, problems should be designed to encourage students to link multiple ideas and concepts together. If the goal of PBL is to make PBL teams successful then problems must be designed to:

- necessitate students to collaborate and value team-work;
- require students to acquire knowledge from various disciplines, integrate that knowledge in finding cross-disciplinary solutions to problems in an innovative way;
- construct learning outcomes that are relevant to the task and clarify what those learning outcomes mean and what students are expected to do to achieve; and
- align assessment with the problem and the expected learning outcomes.

9.3 Limitations of this study

In accordance with the criteria for judging qualitative research and with respect to the transferability of the findings of this study, readers are advised to carefully understand the context in which this study was undertaken (see Chapter 4). While this study has led to some theoretical understanding about group processes and in turn the emerging learning cultures in PBL teams, care has been to taken to understand the phenomena of interest (student experiences of life in PBL) from the participants' perspectives. The main limitation of this study therefore is that the participants are the only ones who can legitimately judge the credibility of the results. Yet, the credibility and trustworthiness of the findings are argued in Chapter 3 with reference to analysis and reporting methods employed in this study.

When interpreting or applying the findings presented in this thesis, readers are advised to be cognisant of the context in which this study was undertaken. That is, it should be remembered that the study was conducted in a first year engineering course. It was the first time problem-based learning had been used as a method of teaching and learning for undergraduate engineering courses in the university where this study was conducted. Hence, it is possible that if this study was conducted at a different stage, say at a higher year level in the course and/or when the School in question had matured in its problem-based teaching practices, it may have yielded rather different student perspectives on their experience in the PBL setting.

It must be noted that student learning approaches and their learning outcomes have a relatively narrow definition in this study. Student learning approaches were identified as deep, achieving or surface approaches based on students' motivation, attitudes and learning behaviours as individuals and as a team. Their learning outcomes studied were limited to the two areas defined by the research questions, namely disciplinary and cross-disciplinary knowledge and innovative thinking. Other learning outcomes, including specific technical knowledge and other core graduate attributes were not investigated.

As indicated before, the focus of this study has been on the student view of life in PBL. Teacher supervision and practices were not explicitly investigated, except as seen through student eyes. Supervisors may have a completely different view of their supervision, including what went well, what worked, what they would do differently and why they would do things differently. Adding their perspectives would provide an opportunity to compare student perspectives of life in PBL with that of their supervisors.

9.4 Implications of this study for practice and research

The interpretations of students' experiences of PBL presented in this thesis confirm that their learning was contextually shaped and situationally determined (Biggs, 2003;

Brown et al., 1989; Lave & Wenger, 1991). This study has provided yet another opportunity to demonstrate that the context exerts a powerful influence on the behaviour of students, their motivation to learn and their willingness to accept responsibility for their own learning.

If PBL is to make a positive impact on student learning, then what must practitioners of PBL consider when implementing and using PBL as either a stand-alone or mixed learning and teaching methodology? The answer to such a question is not simple. It involves a paradigm shift that includes a shift in focus from teaching to learning, a shift in focus from instructivism to constructivism and a shift in focus from teacher-centeredness to learner-centeredness.

The heart of PBL is the PBL team and the team's functionality is influenced by several enabling and inhibiting factors, including student characteristics, their engagement, their attitudes and behaviours towards group learning, supervisor practices and course design and implementation. In the area of course design, Schmidt and Savin-Baden advise us that problem selection and design may be most critical in encouraging student engagement. But good facilitation, appropriate expected learning outcomes and assessment practices that are aligned with PBL goals and expected learning outcomes are important also.

The learning cultures identified in this study through the lived experiences of students in PBL teams represent a hierarchy in terms of their success in supporting learning, with the collaborative learning culture the most successful in engaging students. The role of a PBL facilitator or supervisor was extremely important in supporting and shaping student learning in the team that adopted a collaborative learning culture. This implies that effective learning practices emerge when teachers scaffold student learning by encouraging deep learning skills, nurturing discussion, debate and collaboration in student teams, mentoring leadership skills, and teaching and monitoring group processes and problem solving processes.

Since most teams in this study adopted a finishing or performing learning culture, the real challenge for practitioners of PBL is to prepare students for group work and to monitor group processes early in the course, when teams are establishing relationships and processes, in order to create a learner-centred learning environment that encourages deep learning approaches in individuals and collaborative learning cultures in teams. This may require considerable effort in teaching students how to work effectively as a team, including valuing sharing and collaboration, in addition to teaching them disciplinary knowledge and generic skills.

The extent to which the students gained disciplinary knowledge and generic knowledge in this engineering PBL setting was strongly influenced by how students engaged with the problems or project as individuals and in teams. Therefore supervisors need to be sensitive to student levels of engagement in learning in PBL teams. Particularly, supervisors need to monitor and, if needs be, actively intervene in student engagement in unsupervised team meetings, as teams spend a significant amount of time learning unsupervised in most implementations of PBL in engineering, including the model reported in this study.

If supervisors want to encourage a collaborative learning culture, they need to be sensitive to the signs of a developing finishing or performing culture and to act effectively when they see these signs. From the study reported here, the key warning signs of the development of these learning cultures are poor communication within the team, low participation in unsupervised team meetings, inadequate team leadership, inequitable allocation of tasks and a mosaic approach to report writing. While some of these signs may be detected by the supervisor in supervised team meetings and in assessment products, this monitoring needs to be supplemented by a robust peer assessment system that provides feedback on how effectively the team is working in other settings.

Finally, as noted above, assessment practices and the way assessment was perceived by the students played an important role in the development of the learning culture in each team. Many students apparently believed that all that was necessary to get a good mark was to develop a solution to the problem presented, to produce a technical report that was a mosaic of their individual contributions and to produce a glossy portfolio, the content of which could be recycled in the next subject. Designing assessment tasks and assessment criteria that recognise and reward collaborative learning is a challenge, but it is one that must be addressed in PBL.

Numerous enabling and inhibiting factors that influence student approaches to learning in PBL teams were identified in this study. These findings may be useful in other settings, particularly in informing curriculum development and learning and teaching practices. However, practitioners are advised to consider the context and assumptions that were central to this research study before applying its findings. The stories of students and teams presented in this dissertation could be used as teaching resources by presenting them to students and teachers as case studies to stimulate discussion aimed at identifying effective group learning behaviours and team-work strategies.

Further, the elements of design that were used for constructing the research methodology for this study could be used to design protocols for future research studies that focus on the details of PBL processes in teams. This could include using methods such as video-taped observations or focus group interviews for collecting and managing continuous data fragments about student learning in PBL settings. The framework of factors influencing learning cultures could be adapted to develop observation or interview protocols or structured questionnaires. The simulated problem solving that was used in this study as an experiment to identify students' application of knowledge that they acquired through PBL tutorials could be used as a method of student assessment in regular PBL classrooms.

As this study was not longitudinal but a snapshot of student experience in the first year of their course, there was no scope for studying what knowledge and skills students develop through problem-based learning during their entire four year course and how they transferred that knowledge and skills into practice in a work place setting. These questions could be the basis for further valuable research studies into student learning. The main findings of this study about the enabling and inhibiting factors that contributed to the relative success of PBL teams also provide impetus for further research into collaborative learning.

9.5 Conclusions

In conclusion, this study has investigated the experiences of first year electrical engineering students in a newly implemented engineering PBL setting. It has identified key elements of team membership, group processes, leadership, individual learning approaches and approaches to PBL that shaped the different learning cultures that developed in the teams studied. Looking at these factors from students' perspectives has shed light on how students respond to a PBL setting, what they prefer to learn and how they actually go about learning it.

Only one PBL team developed and consistently used a collaborative learning culture. The members of this team valued active participation, inclusiveness, mutual respect and a deep approach to learning. They used effective group processes such as regular communication, discussion and regular face-to-face meetings. These positive practices contributed to the success of their team. Leadership was also important when the team leader motivated team members, encouraged discussing ideas and findings and sharing learning. All of this promoted collaboration and therefore enhanced the opportunity for making the PBL team successful.

Students observed in this PBL setting were from diverse socio-economic, age, ethnic, school and work experience backgrounds. Their diversity such as age, gender, ethnicity, social, family and work life, and personal and career motivations may interact with their learning over time. However, neither homogeneous nor heterogeneous team consistently adopted a collaborative learning culture. Teachers need to think about ways of enhancing the quality of learning in teams by helping students to value heterogeneity in teams.

The findings of this study imply that a large amount of responsibility still remains with the teachers, the course design and the way it is implemented. This means that educators need to focus on developing or enhancing teaching strategies that help students collaborate and thus make PBL teams successful. All PBL teams can achieve success if teachers encourage students to approach learning at a deep level, use effective group processes and problem-solving processes, develop leadership skills and develop collaborative skills. Teachers can do this by using a judicious mix of modelling, scaffolding, coaching and fading. To do this effectively, they also need to monitor how the team is performing and to intervene appropriately when there are problems.

If our teaching involves placing students in complex teamwork situations, then it is important to understand the significance of team membership, group processes, team leadership and learning approaches that shape learning within small groups in PBL. If we are to encourage and sustain courses of this kind, then we have an educational duty to provide our students with the basic tools required for supporting their learning. That is, it is important to create valuable learning experiences by closely monitoring and coaching students in learning collaboratively as a team.

By helping students to learn how to be part of a team, how to respect diversity within the team, how to be inclusive of fellow team members, how to take various team roles and responsibilities and how to collaborate, we can make student teams function more like Team 8 and less like Teams 1, 2 and 3. If practiced wisely, PBL can make a difference in how and what students learn in classrooms and how they transfer this learning into real life work situations. This way, not only students but also teachers will feel a sense of accomplishment.

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Appendices

Appendix 1 Sample field notes

Observation Field notes: Week 7, Semester 1.

Date: 24.04.2006

Team observed: Team 4

Duration: 35 min

Students present: Timothy, Rajesh, Mike, and Arjuna

Location: Suite 5

Type of meeting: Supervised

Students in this team were talking about Problem 3 as I entered the suite to observe them. I excused my self and found myself a place so that I could see everyone in the team. The supervisor of the team welcomed my presence and started to speak up a little bit.

The supervisor repeated what they were speaking when I entered the classroom. Timothy said, voltage splitter, current splitter. Will you be able to get out of these? He asked the supervisor, showing him a piece of paper in which there was a hand drawn circuit diagram.

The supervisor said I will give you the entire problem now. What ever is up to page 5 in this, we will have a look at it now. The details that are after page 5 we will leave it for later.

You know what your problem is right?
The supervisor starts reading out the problem from his copy. When he started to read out about role play, Timothy said, Role play – hmm

The supervisor continued to read and said, as soon as we finish this session, I will introduce you to a software that will help you to role play. I hope you have all done you job. Tell the rest of the team what the test procedure will be.

The supervisor then started to explain the team about the learning outcomes. He stressed the words time management, construction skills while reading out the information to the team. The Supervisor then asked can one of you read out to the rest what is mentioned in learning outcomes 9, 10 and 11.

Mike raised his hand showing that he wanted to volunteer to read that out. The supervisor looked at him and said: Go on. After Mike finished reading out, the supervisor started to explain the learning outcomes. He said: You are all expected to play a role. Each one of you will get assigned to a member. I will prefer that you don't tell your other team members and your friends who you are. By not saying your name, it will make it more interesting.

Mike asked, what is the aim of it?
The supervisor said, on the software, you will have to fill out your profile, you can say, I am 80 years old, make up something. It is to go concurrently with your technical description on WebCT. The supervisor then read out the roles to the team. He mentions the possibility of a debate that could happen. After this, the supervisor said to the team, alright guys, can someone tell me the overall picture of the problem.

None of the students opened their mouth. Timothy was looking at me, Mike and Arjuna was laughing at each other. Rajesh had his head down. He did not have eye contact with anybody.

The supervisor then said, you are supposed to use the software for technical discussions and debate from now till the end of the semester. You have to be active in this role. You need to post at least 4 messages per person ever week.

I am happy with what you have come up here, points to the circuit diagram Timothy had drawn on the board. You need to indicate the type of battery you will be using. Specify the switch.

The supervisor asked: how did you come up with the circuit? Timothy said, we just made it now. The supervisor then said, good. Hook this up on a bread board before you commit to this circuit diagram. Put in extra stuff like LED to slow down the charging. Put a diode to stop the reverse current flowing.

The students looked confused with the information that they just received about reverse current flow. The supervisor noticed this and started to explain more about it. He said: when you have more voltage in the battery than the solar panel, then it may turn back into the panel.

Apart from Timothy and Mike, no other student in the team engaged in any conversation. Supervisor initiated all the conversation during the team meeting.

The supervisor asked where Walter was. Timothy said, he has missed 3 - 4 meetings. Can we ring him up? The supervisor said: by all means. He is missing a fair bit, talk to him and tell him what his responsibilities are. He has a high chance of failing this subject.

Timothy said, I did not even choose the testing side of it, and I have already started to do it. The supervisor then said, well email it to me. Think about the financial side as well. Don’t go too much. Mike asked: Do we have to mention the tolerance as well? The supervisor did not answer this question. The rest of the team looked like they did not understand what was going on.

The supervisor then said, think about the time lines. Week 10 is your presentation. You have two more weeks to finish up all the testing before week 10.

Mike said: that's one thing [time management] that we have learnt from our last project.

The Supervisor then started to hint them about how the next semester PBL subject will be. He said: There will be just one project for the entire semester. Your team will have to work on solving the project. He then said are we all clear about what is required for this problem?

Students in the team started to nod and packed their bags. Timothy asked: Are there any rules of things that we can talk about?

The supervisor then explained more about the way the software for discussion is structured. He said, "Well there are two areas in the software. There is a board room and a cafeteria. In the board room you are expected to be a professional. In the cafeteria, you can be casual. Is that clear?"

Mike and Arjuna left the team for that day while the supervisor was still explaining the software.

Appendix 2 Sample of the transcript of a Video-taped observation

Observation transcript: Team 7 supervised team meeting
Date: 25.09.2006

Team members: Bruce, Phillip, Alex, PBL supervisor (PBLS) and Language and communication Supervisor (LCS)

Start time: 4.15 pm

Bruce: This is the circuit diagram that we downloaded from the internet.
PBLS: What?
Bruce: yeah, you would have to specify it to our situation here. This is pretty much the format of how you do it using Karnaught maps.
PBLS: Yeah, I expect this in your report. In case of using K-maps, you may be able to do all of this [points to the computer screen]. I still expect you to come up with all these equations to explain me. This is the one is it? [looks at Bruce's work sheet]. You should be able to explain what this is? What this means? Ok?
Bruce: that's easy [looks at Phillip and smiles]
Phillip: I did the parts list and stuff for the main circuit.
PBLS: You must be able to explain why you need a JK flip-flop. Ok? What's the J input. What's the K input? What's the output, what's the logic equation for the output? What's this output doing? Is it driving something? [Pointing to the computer screen] Can you go back?
Bruce: Ah, yes. [Turns the computer to his side]
PBLS: See, the output is feeded into an OR gate. Why? The outputs of the OR gates are feeded into the input pins of this counter. What's this doing? OK? Is it counting?
Bruce: it is [trys to say something, but the PBLS blocks his communication]
PBLS: Is it counting from 1 to 16?
Bruce: We have a decade counter. So it will be counting up to nine and then will reset to zero.
PBLS: but you can then adjust it by changing those inputs. OK? Those inputs determine the sequence it counts.
Bruce: yeah, these counters here are those once there. [refers to the previous picture on his computer screen]
PBLS: What are they the output pins?
Bruce: yeah, these are the output pins.
[Phillip loses his concentration by this time and is looking elsewhere, he takes his cap off and puts it back on]
Bruce: that's what the output pins are.
PBLS: Start
Bruce: Pardon?
PBLS: are these diodes?
Bruce: Yeah, diodes and LED's and resistors on the outputs. Umm, Phillip found out what sort of diodes they were, [looks at Phillip] didn't u?
Phillip: Yeah, it all on the list
PBLS: Where is the list?
Bruce: Parts list ahh [searches his computer folder for the list] here it is. Phillip got it up-to-date.

PBLS: 24 yellow LED's. Why?
Phillip: Well the idea is. I presume you want us to present this don't you? The problem is you won't be able to see it. So I was thinking if you are going to be connecting them in series, then the 24 would be for the four turning arrows.
So for example, if you put six in each lot and arrange it in the shape of a turning arrow. That was the only reason why, I thought of doing it that way. If you have one set of LED's which exactly the same are, then you can't tell which one is for turning unless it looks like an arrow.
LCS: I understand what you mean.
Bruce: and for the other for example the green light, put four together like two on top of each other.
LCS: Yeah, but haven't you thought of having a structure on top so that you can actually blackout some of it so you could actually see. It could be connected to LED, but you may not need that many. You can actually blackout others so you can see it flash. [The language and communication supervisor seems to provide engineering solutions here]
PBLS: it's going to be really costly.
LCS: yeah, you could do it better I think.
Bruce: they are what 10 cents each?
Phillip: 20
Bruce: How much is each group allocated?
PBLS: I am not too sure but,
Bruce: Not that much? Well you can just go one line but it will look shitty.
PBLS: Pardon?
Bruce: We can go one light in each traffic light, but you know one light
PBLS: it should be sufficient. One light.
Phillip: I was looking at the power side and it does not take that much power to run the LEDs.
Bruce: One disadvantage is, the circuit that we got of the internet is only designed for one LED per light. So and then if you start tinkering with the number of LEDs you chuck in there it might start dimming the whole circuit. Because you are supposed to have a certain amount of power running through them.
PBLS: Next time please try to have a print-out of these documents.
Bruce: Its greener like this.
PBLS: yeah, but then I need to print them myself. It is a cost to our department.
Bruce: what 3 cents a sheet or something?
PBLS: Yeah, my Head of School is worried about that.
Bruce: it costs us 10 cents to print at the library.
PBLS: the circuit looks all fine. I am glad that you have come up with some thing.
Alex was quiet through out the meeting. No one asked why he was quiet nor he was encouraged to speak.

Appendix 3 Interview questions – Semester 1

3.1 Focus group interview questions:

1. What is your understanding about problem based learning curriculum?
2. How do you feel when you are told that you are given more responsibility for your learning?
3. Do you like the idea of learning a subject by solving problems?
4. What are your expectations about learning electrical engineering?
5. What are generic skills? How do you expect to learn them?
6. What do you like or dislike about working in a group?
7. How does your group work together?
8. What do you feel about sharing your point in the group meetings?
9. What experiences have you had of problem solving before coming to university?
10. What are the facilitator's contributions to your and your group's learning? How does the facilitator assist you and your group's learning?
11. How are critical issues addressed and resolved in your group?
12. Do you approach your facilitator about any subject matter that you need clarification?
13. What is your facilitators approach towards helping you out in your queries?
14. Does your group prepare an agenda before meeting with your facilitator? Who does that?
15. What are the different roles that you and your group members take in order to form a successful team?
16. What do you say about learning in a group? Does that help your learning?

3.2 Individual interview questions:

1. What do you feel about learning in the PBL curriculum?
2. What do you think about your understanding of the learning outcomes (to be specified when documentation is available) as specified in the subject documentation and as explained by your facilitator?
3. How does your group work together?
4. What do you feel about sharing your point in the group meetings?
5. What are the facilitator's contributions to your and your group's learning? How did the facilitator assist you and your group's learning?
6. What are the tasks given to you as well as your group by the facilitator or other members of the group?
7. What is your contribution to the group's learning?
8. What are your comments about the interaction within the group?
9. Whom have you spoken to about any issues or problems that you might have had while participating in the group?
10. How have you approached a particular task? How did you go about solving that? What are the other materials that you used as support for completing the task along with the materials suggested to you or/and your group by your teacher?
11. What other disciplines have you looked into while solving a problem?
12. What is in your portfolio that shows your innovation to the problem solving?

13. Tell me about tasks that you have taken that demonstrate cross-disciplinary learning?
14. What in your portfolio that is different from that in other members of your group?

Appendix 4 Interview questions – Semester 2

4.1 Focus group interview questions:

1. How do you approach problem solving?
2. What responsibilities do you take and why?
3. What generic skills are you learning?
4. What are the different roles that you and your group members take in order to form a successful team?
5. How much time do you spend with your group? Where do you meet?
6. How does your group work together this semester?
7. What do you like or dislike about working in a group?
8. How does your supervisor help you with your queries?
9. How does your supervisor help you with your learning?
10. What did not go well last semester and how are you addressing that this semester?
11. How many times has your group prepared an agenda this semester? How and when do you give that to your supervisor?
12. If PBL is the way of learning in your future semesters at VU would you continue?
13. What strategies have you put in place for your group's learning?

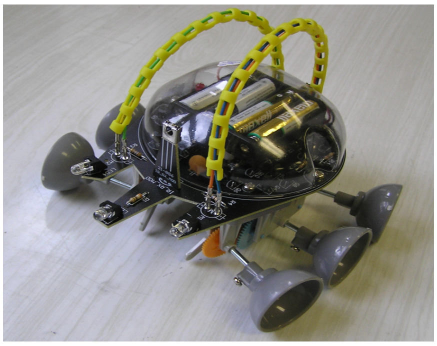
4.2 Individual interview questions:

1. What is your understanding of PBL now?
2. How do you understand your learning outcomes?
3. How does your group work together this semester?
4. What do you feel about sharing your point in the group meetings this semester? What is better / worse?
5. What are your supervisor's contributions to your and your group's learning? How did your supervisor assist your learning?
6. What are the tasks given to you by your supervisor or other members of the group?
7. What is your contribution in problem solving?
8. How did you interact with your group for problem solving?
9. Did you have any issues about your group's participation? Whom have you spoken to about any issues or problems that you might have had while participating in the group?
10. How have you approached a particular task? How did you go about solving that? What resources have you used for completing the task? Did your supervisor suggest any particular text book or material that you could use for problem solving?
11. What other disciplines have you looked into while solving a problem?
12. What is in your portfolio that shows your originality or creativity?

Appendix 5 Course documents

5.1 Semester 1 – Problem 1:

Escape: Robot Kit Construction



1.0 Preamble and Problem Description

You are required to construct a mobile robot (commercially available kit). Primarily this exercise is intended as a means whereby you will be formed into teams of (up to) five within the group which was formed on orientation day. As one of the team members you should help each other to make sure all the robots constructed are working within the team. Each team needs to demonstrate all the robots to the supervisor. You are also required to participate in the workshops on Occupational Health and Safety, component handling and soldering and information literacy. You also need to understand and embrace the concepts of PBL, and be ready for this mode of learning. An introductory written exercise (Self Profile) requiring you to introduce yourself to your supervisor and co-supervisor is to be submitted to both your supervisor and co-supervisor by 5pm on Monday in week 2. The constructed kit will be retained for you for subsequent use in a later exercise (it is anticipated that you will replace the provided microprocessor by one that you are to program yourself).

2.0 Deliverables

On the completion of this problem, you and your team will have produced the following deliverables:

a) Robots are to be delivered to your supervisor (Due: Friday, 4pm of week 1)
b) A written exercise – Self Profile (written exercise) to be submitted to your supervisor and co-supervisor (Due: Monday, 5pm of week 2) The exercise is to be approximately 500 - 800 words in length, word processed and presented in accordance with PBL assessment criteria. In your written exercise you are required to:

Write a short account to introduce yourself to your supervisor and co-supervisor. Give brief biographical data – e.g. family background, where you live, part-time jobs, hobbies etc.

- Outline the language/s other than English with which you are familiar. Describe your competency in this language/s. For example, are you able to understand the spoken language but find difficulty in communicating in writing or speaking?
- What communication skills would you like to develop during your PBL Engineering course? This question requires you to think about your strengths and weaknesses as a communicator and focus on the areas in which you would like to see improvement. (Remember that the term communication skills includes a wide range of possibilities, for example, interpersonal skills, intercultural communication skills and listening skills, in addition to academic English language written and spoken skills.)

Remember to plan your answer and write your response in paragraph form. It is important to keep this exercise in your portfolio for future reference.

3.0 Timeline

You are to commence the problem once the Introductory Session ends and hand over your findings to your supervisor within the time specified in the table below. The dates are as follows:

Introductory Session on Problem	Monday afternoon, week 1, in scheduled "introduction to soldering workshop" with your supervisor
Individual Written Exercise	Monday, 5pm of Week 2 to supervisor and co-supervisor
Delivery of Robot kits to supervisor	Friday, 4pm, Week 1

4.0 Desired Learning Outcomes

The desired learning outcomes of this first PBL problem are:

PL1. Be able to form into and work cooperatively in teams of (up to) five and be allocated by team to a Supervisor. [You must use this exercise to identify colleagues with whom you will be teamed for subsequent exercises].

PL2. Be able to articulate the concepts of PBL, and of the expected contribution and work requirements of this program.

PL3. Understand basic safety issues, especially those relevant to the immediate exercises (i.e. general safety and electronics construction).

PL4. Develop basic skills in soldering and handling of components.

PL5. Develop basic skills in library usage and information literacy.

PL6. Demonstrate ability in writing about your background and communication competence.

PL7. Demonstrate abilities in time management.

The learning outcomes mapped to the Engineers Australia Graduate Attributes and enhanced by the addition of VU Core Graduate Attribute number 2, as in A11, are as follows:

5.0 Matrix of Graduate Attributes vs. Learning Outcomes

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	Unit of Study Learning Outcomes
PL1		√				√						UL13
PL2		√								√		UL15
PL3							√		√			UL5
PL4	√		√									UL2, UL11
PL5											√	UL9
PL6		√		√						√		UL3, UL8
PL7				√		√			√			UL14

where:

A1. Ability to apply knowledge of basic science and engineering fundamentals.

A2. Ability to communicate effectively, not only with engineers but also with the community at large.

A3. In-depth technical competence in at least one engineering discipline.

A4. Ability to undertake problem identification, formulation and solution.

A5. Ability to utilise a systems approach to design and operational performance.

A6. Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member.

A7. Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development.

A8. Understanding of the principles of sustainable design and development.

A9. Understanding of professional and ethical responsibilities and commitment to them.

A10. Expectation of the need to undertake lifelong learning, and capacity to do so.

A11. Ability to locate, evaluate, manage and use information effectively.

5.2 Semester 1 – Problem 2:

K-5604 -The Champ: Audio Amplifier

1.0 Preamble and Problem Description

You have recently being employed by "Kits R US Australia", a well recognised company in the electronics industry. A major competitor in the production and design of electronics kits is "Dick Smith Electronics". Your company is thinking about producing an audio amplifier, which is similar in operation to the "K-5604 - The Champ: Audio Amplifier" produced by Dick Smith Electronics. Your task with "Kits R US Australia" is to construct and test the K-5604 audio Amplifier from Dick Smith Electronics, and report back to your supervisor on your findings. The K-5604 kit will be given to you by your supervisor. The K-5604 design is a single channel audio power Amplifier, which delivers 0.5W of power into 8 ohms, from a 9V supply, with variable internal gain from 20 to 200. The Amplifier can be used for a variety of audio projects. The module uses the well-known LM386 audio amplifier Integrated Circuit (IC). It is small and most importantly, low cost.

Some of the things that you will have to report back on will be the use of the electronic equipment used to test the constructed design, and some of the measurement taking techniques you learned. As part of your reporting back to your supervisors, you will need to submit, as a team, a written technical report, and an individual reflective written exercise, including an account of your adjustment to life as an engineering student at Victoria University. In addition, you will be required to deliver a group oral presentation to summarise your findings and the knowledge that you have gained from the problem.

1.1 Further Advanced Topics

If time permits, your team could also investigate the use of different types of battery with this amplifier.

1.2 Expected Tasks

You are expected to:

a) Investigate and understand the process of amplification.
b) Understand the relationships between 'Volts', 'Amps', 'Ohms' and Power.
c) Investigate and identify the components that are used in this amplifier.
d) Construct the amplifier (All components will be purchased and given to you by your supervisor).
e) Measure the amplifier frequency response, firstly by using a multimeter, then perform the measurement by using an oscilloscope. Compare the results. Which one do you think is the correct measurement?

f) Test the amplifier with various types of batteries (All test equipment can be found in your laboratory, G209) – *This is for the advanced optional topic.*
g) Determine which type of battery gives you best results, and explain why? – *This is for the advanced optional topic.*
h) Produce a team written technical report as described below (Section 2.0).
i) Reflect on your experience as an engineering student in an individual written exercise.
j) Prepare and present as a team, a PowerPoint presentation to your supervisors. The presentation must contain your entire findings and recommendations on this exercise.

2.0 Deliverables

On the completion of this problem, you and your team will have produced the following deliverables:

a) Team Technical Report entitled: "The K5604 - The Champ: Audio Amplifier". The report should comment upon the construction of the kit and the instructions provided as part of the kit. It should present the performance measurements made of this amplifier, detailing measurement techniques used. (Approx 1500-2000 words.) Due: Monday, 5pm of Week 6) [This report should be word processed and written for your supervisors in their role as your managers at "Kits R Us Australia".]

b) Individual Reflective written exercise (word processed, approx 800 words). Due: Monday, 5pm of Week 6) In this exercise you are required to produce an account of your individual progress by responding to the following:

   - are you adjusting to life as a student in Electrical Engineering at Victoria University?
   - What are you enjoying/finding a challenge about PBL?
   - How are you coping with non PBL units of study?
   - What have you learned from PBL problem 1 (Robot Kit) about working in a team, problem solving and time management?

   [This exercise should be written for your supervisors to help them understand the difficulties that you are meeting in the course.]
   Remember to plan your answer and write your response in paragraph form. It is important to keep this exercise in your portfolio for future reference.

c) Team Oral Presentation – 30 minutes for the team
   The presentation duration is 30 minutes in which each team member will present for approximately 5 minutes per person on their contribution to the problem. There will be about 5 minutes remaining for questions and answers. (Due: Week 5 during PBL meeting).
d) All items to be included in your Portfolio.

3.0 Timeline

The problem has the following deadlines. You are to commence the problem once the Introductory Session ends and hand over your findings to your supervisor within the time specified in the table below.

Introductory Session	Week 2 scheduled meeting with supervisor
Presentation Date	Week 5 scheduled meeting with supervisor and to your team
Team Technical Report Due	Monday, 5pm of Week 6 to supervisor and co-supervisor
Individual Reflective Exercise Due	Monday, 5pm of Week 6 to supervisor and co-supervisor

4.0 Desired Learning Outcomes

The desired learning outcomes of this problem are as follows:

PL1. Further development of electronic circuit construction skills. Further practice in soldering. Development of ability to identify electronic components.

PL2. Ability to use basic electronic equipment: DC PSU, oscilloscope, signal generator, digital multimeter.

PL3. Development of ability to take measurements, and record these in a laboratory log book.

PL4. Production of a team technical report on the measured performance of an amplifier. This exercise may include the use of Excel for data presentation.

PL5. Production of an individual reflective written exercise.

PL6. Ability to work as part of a team and successfully complete this problem in a specified time period.

PL7. Location, evaluation, management and critical utilisation of information to successfully complete this problem.

PL8. Development of oral presentation skills.

The learning outcomes are mapped to the Engineers Australia Graduate Attributes and enhanced by the addition of VU Core Graduate Attribute number 2, as in A11, are as follows:

5.0 Matrix of Graduate Attributes vs. Learning Outcomes

	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	Unit of Study Learning Outcomes
L1	√		√									UL2, UL10, UL11
L2	√		√			√				√	√	UL2, UL10, UL11
L3	√	√	√			√				√	√	UL2, UL8, UL11
L4	√	√	√	√		√				√	√	UL3, UL4, UL12, UL13
L5		√		√		√	√			√	√	UL3, UL8, UL15
L6		√		√		√			√	√	√	UL4, UL8, UL13, UL14
L7	√	√	√	√		√				√	√	UL9
L8		√		√		√				√	√	UL4, UL8, UL15

where:

A11. Ability to apply knowledge of basic science and engineering fundamentals.

A12. Ability to communicate effectively, not only with engineers but also with the community at large.

A13. In-depth technical competence in at least one engineering discipline.

A14. Ability to undertake problem identification, formulation and solution.

A15. Ability to utilise a systems approach to design and operational performance.

A16. Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member.

A17. Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development.

A18. Understanding of the principles of sustainable design and development.

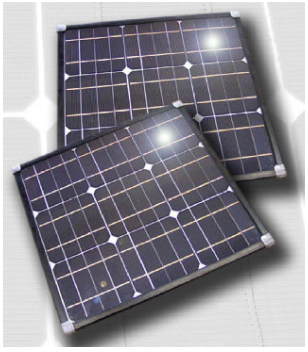
A19. Understanding of professional and ethical responsibilities and commitment to them.

A20. Expectation of the need to undertake lifelong learning, and capacity to do so.

A11. Ability to locate, evaluate, manage and use information effectively.

5.3 Semester 1 – Problem 3:

Renewable Energy



1.0 Preamble and Problem Description

You have just graduated and have been recruited by the Green Power and Energy Pty Ltd., a company that produces small-scale (up to 10KW) hydro and wind power systems. The company has decided to investigate adding solar power systems to its product line, although it has no experience in using solar arrays (based on photovoltaic cells).

You are part of a team of fresh recruits, given the task of investigating the suitability of such products to this company. The brief given to your team has two main components:

1) To investigate the suitability of photovoltaic array/battery systems as primary sources of energy. You have been advised that the company's founder and owner have a deep commitment to sustainability and the environment. The owner suspects that such systems may have an overall negative impact on the environment, and be only suitable for use in remote locations that have no mains electricity connection. There are concerns about the ability of such systems to recoup embedded energy, pollution both in the manufacture and end-of-life of the components, in addition to the more conventional concerns of purchase and operation costs, reliability of energy supply etc. Your team is to produce a referenced research report recommending whether or not the company should proceed with its plans to add such systems to its range.

2) The company has issued your team with a small array of photovoltaic cells and a battery. They have asked that you design and perform experiments using these to assess their performance and suitability for use as an alternative energy system.

The company is a member of the Australasian Alternative Energy Association, an association of businesses in the renewable energy industry. Members of this Association want to avoid duplication of research effort, and your team must register its planned experiments with your team supervisor, who will submit the plans to the Association. The plan should not exceed one side of an A4 sheet, and work should not commence until approval of the experiment has been received.

Your team is to also consider the greater social implications of Renewable Energy from many viewpoints such as: company owner, end users, and representatives from the Australian Alternative Energy Association, movements fighting for and fighting against greener technology. Your team has to understand the context of solar energy to be able to analyse the technology and ethical issues in a social context.

1.1 Expected Tasks

You are expected to:

a) Investigate various types of rechargeable batteries
b) Investigate the properties of photovoltaic cells (solar panels)
c) Role Play the various characters in relation to the social aspects of this problem to obtain an understanding of some of the greater issues in the engineering profession.
d) Build circuits to investigate the charge and discharge characteristics of the batteries.
e) Investigate the use of test and measurement equipment to assist in circuit testing
f) Write a Team Research Report on your findings concerning the use of solar arrays as primary sources of power.
g) Write an individual reflective response to your experience of PBL in this semester.
h) Prepare and present a PowerPoint presentation to your group. The presentation must contain your entire findings and conclusions.

2.0 Deliverables

On the completion of this problem, you and your team will have produced the following deliverables:

e) Team Research Report on the investigation whether or not photovoltaic array/battery systems are suitable as primary sources of energy. Include a description of the experiments you designed and the results and conclusions drawn from these experiments. (Approx 1500-2000 words. Due: Friday, 5pm of Week 10)

   Your report must be word processed in standard report format (*Handbook* pp.20-31). Paraphrase, i.e. use your own words. Do not copy or cut and paste information from sources (*Handbook* pp.16-19). This is plagiarism (*Handbook* p.48, p.82). Provide in-text references for every source of information (*Handbook* pp.82-88). Provide a Reference List for every source of information (*Handbook* pp. 88-94). In addition to a hard copy of the report, you must also submit an electronic version to http://turnitin.com (a plagiarism detector).

f) Individual Reflective Response describing your experiences in the PBL component of your course in this semester. (Approx 1000 words. Due: Friday, 5pm of Week 10)
g) Team Oral Presentation – 30 minutes for the team
   The presentation duration is 1 hour in which each team member will present for approximately 10 minutes per person on their contribution to the problem. There

will be about 10 minutes remaining for questions and answers. (Due: Week 10 during PBL meeting)

h) All items to be included in your Portfolio.

3.0 Timeline

The problem has the following deadlines. You are to commence the problem once the introductory session ends and hand over your findings to your supervisor within the time specified in the table below. The dates are as follows:

Introductory Session	Week 6 scheduled meeting with supervisor
Presentation Date	Week 10 scheduled meeting with supervisor and to your group
Team Research Report Due	Friday, 5pm of Week 10 to supervisor and co-supervisor
Individual Reflective Exercise Due	Friday, 5pm of Week 10 to supervisor and co-supervisor

4.0 Desired Learning Outcomes

The desired learning outcomes of this problem are as follows:

PL1. Demonstrate an ability to work as part of a team and successfully complete this project in a specified time period.

PL2. Demonstrate abilities in time management.

PL3. Locate, evaluate, manage and critically utilise information to successfully complete this project.

PL4. Further developed electronic circuit construction skills including further practice in soldering.

PL5. Utilise basic electronic devices and incorporate them into a working design, i.e. 'battery charger by use of photovoltaic cells'.

PL6. Operate a range of standard electrical engineering laboratory equipment to take measurements, and record these in a laboratory log book.

PL7. Use a computer to perform word processing, create spreadsheets and graphical outputs as a communication tool. This includes the production of a team report and an individual reflective exercise.

PL8. Create and Deliver Visual/Oral Presentation with PowerPoint and answer questions during the presentation.

PL9. Develop familiarity with the concept of renewable energy, sustainability and the greater issues of engineering.

The learning outcomes are mapped to the Engineers Australia Graduate Attributes and enhanced by the addition of VU Core Graduate Attribute number 2, as in A11, are as follows:

	A1	**A2**	**A3**	**A4**	**A5**	**A6**	**A7**	**A8**	**A9**	**A10**	**A11**	**Unit of Study Learning Outcomes**
L1		√		√		√			√	√	√	UL1, UL8, UL13, UL14
L2						√			√	√		UL14
L3	√	√		√	√	√	√	√		√	√	UL9
L4	√									√		UL2, UL10, UL11
L5	√	√	√	√	√	√	√	√	√	√	√	UL2, UL7, UL10, UL11
L6	√	√	√	√		√			√	√	√	UL2, UL8, UL11
L7		√				√				√	√	UL3, UL4, UL8, UL13, UL15
L8	√	√	√			√				√	√	UL6, UL8
L9	√		√				√	√	√	√	√	UL6, UL7

where:

A21. Ability to apply knowledge of basic science and engineering fundamentals.

A22. Ability to communicate effectively, not only with engineers but also with the community at large.

A23. In-depth technical competence in at least one engineering discipline.

A24. Ability to understand problem identification, formulation and solution.

A25. Ability to utilise a systems approach to design and operational performance.

A26. Ability to function effectively as an individual and in multi-disciplinary and multi-cultural teams, with the capacity to be a leader or manager as well as an effective team member.

A27. Understanding of the social, cultural, global and environmental responsibilities of the professional engineer, and the need for sustainable development.

A28. Understanding of the principles of sustainable design and development.

A29. Understanding of professional and ethical responsibilities and commitment to them.

A30. Expectation of the need to undertake lifelong learning, and capacity to do so.

A11. Ability to locate, evaluate, manage and use information effectively.

5.4 Semester 2 – Project:

Traffic Automation

1.0 Preamble and Problem Description

You have been recently recruited by digital solutions (DS) Pty. Ltd and you have been assigned your first project in traffic automation.

DS has been contracted by Vic Roads to investigate and automate a traffic intersection which has a traffic light timing problem. Such problem occurs at intersections which consists of a main road that is used for people commuting to work, and a side street that is mostly used by local residents. Currently the traffic system at such an intersection runs on a timer that does not consider the traffic flow during peak times, hence the timings are fixed. Problems as such have been reported to be inefficient by commuters as they have expressed their complaints to the local civic centre.

DS Pty Ltd has 9 weeks inclusive to provide a solution to this problem by providing a proof of concept, implement the concept and report to Vic Roads. Vic Roads would like the intersection automated to increase its efficiency by making the timing adaptable based in traffic flow.

Appendix 6 Sample from students' portfolios

6.1 Claire's portfolio - Semester 1

2.0 LEARNING OUCOMES

2.1 Demonstrate the successful completion of a project(s) in a specified time period.

Project Based Learning (PBL) for this semester was broken into three projects. The first of these was done individually and was to be completed over one week. The project consisted of soldering and some mechanical construction. At the completion of this project, a short reflective on our individual backgrounds was required.

Project two was completed as a group and also required soldering. This project had a longer, yet far stricter time line. The project requirements were given to us gradually with 5 weeks allocated to complete the task. Research was to be completed during the first week, soldering in the second and testing of circuit was done over the next few weeks. Week four required a presentation to be delivered by the team to our supervisors explaining our contribution to the project in language fitting for the professional and non-professional as appropriate. The following week, a complete report was submitted along with an individual reflective describing our transition into University.

Project three had similar requirements with less soldering required. The timeline for this project, however, was extended. The draft for this project was submitted on Monday, May 22nd, (the beginning of the sixth week of the project) along with a reflective draft comparing PBL to past and present learning experiences. At the end of the projects fifth week, the team presented an oral presentation to all of group D detailing our contribution to the project.

The completed projects including reports, presentations, project outlines and reflectives in section 3.0 support this claim.

The completed projects were all submitted on time and in some cases, earlier than required.

2.2 Demonstrate professional engineering skills.

Each project required a certain amount of soldering, refining our skill in this area, as well as following instructions of varying detail to assemble the circuit. More advanced skills were essential in Project Two to operate the required testing equipment. To complete the necessary project requirements, oscilliscopes, multimetres, function generators and a power supply unit were used.

It proved difficult for all groups to acquire the skills to use this equipment correctly, but between the five team members, we were able to work out how each piece of equipment could best be utlised and how it was to be attached to the circuit. Details in project two confirm our use of this equipment (see section 3.2.3).

Project three asked for each team to design, or to research a design for a circuit to be used as a charge controller and then to assemble the circuit. While our charge controller was simple (see section 3.3.3, pg 10), it still required an understanding of circuit components.

2.3 Use a computer to perform word processing as a communication tool.

Throughout the semester, computers were employed on various occasions as forms of communication. Each report and reflective was completed using the programs Word and Excel from the Microsoft Office Suite. These can be seen in section 3.0.

Several different email applications were used for communication also. Hotmail, Gmail, Outlook and WebCT were used to maintain contact with team members in between meetings and classes. Section 6.1 displays a sample of emails from during the semester and the WebCT print out is at 6.7.

As part of project three, an internet application known as "Fablusi" was engaged for the purpose of online debate. This required use of a computer and frequent message posting as illustrated in Figures 1 and 2 and in full at section 6.2.

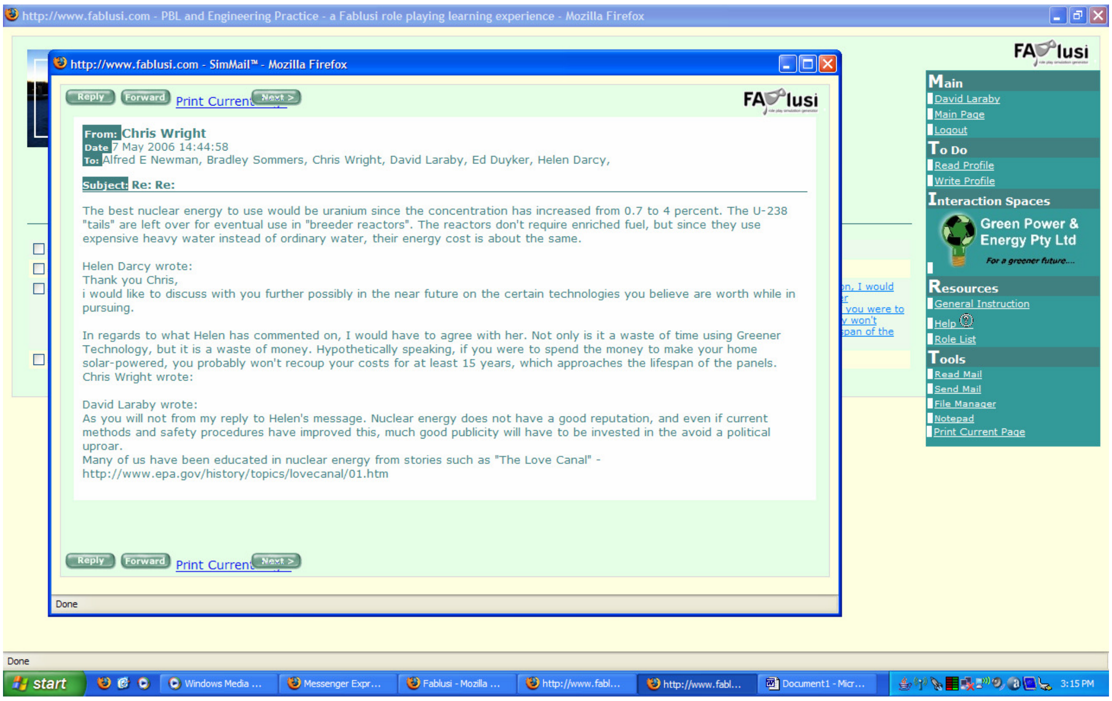


Figure 1 An email created for use during the “Fablusi” aspect of project 3.

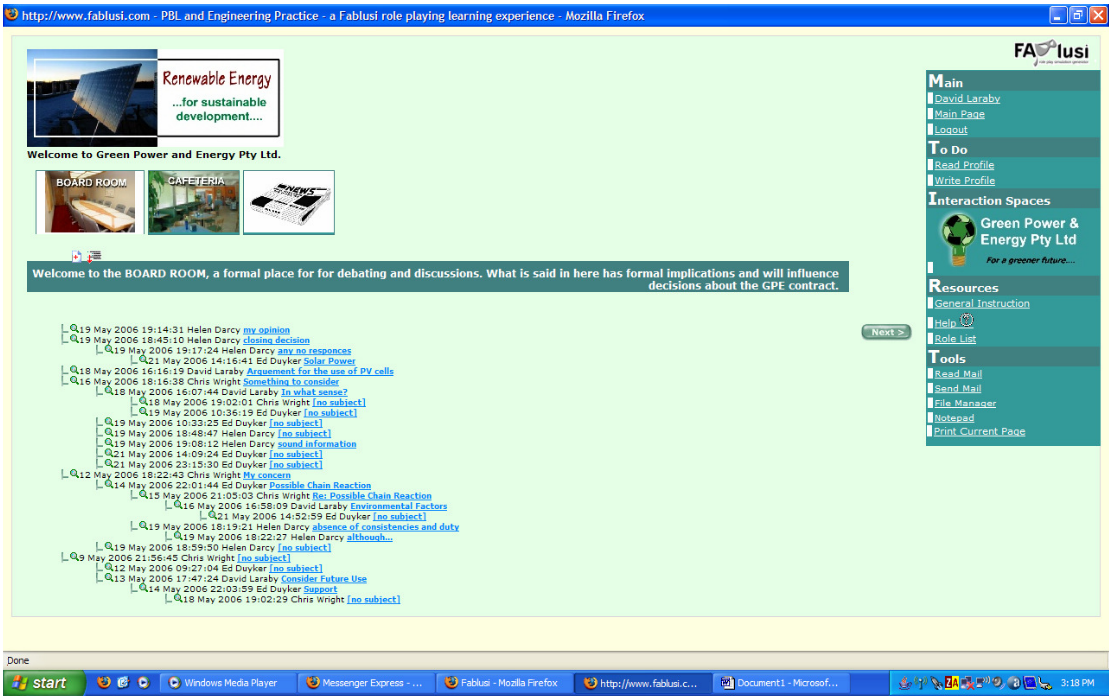
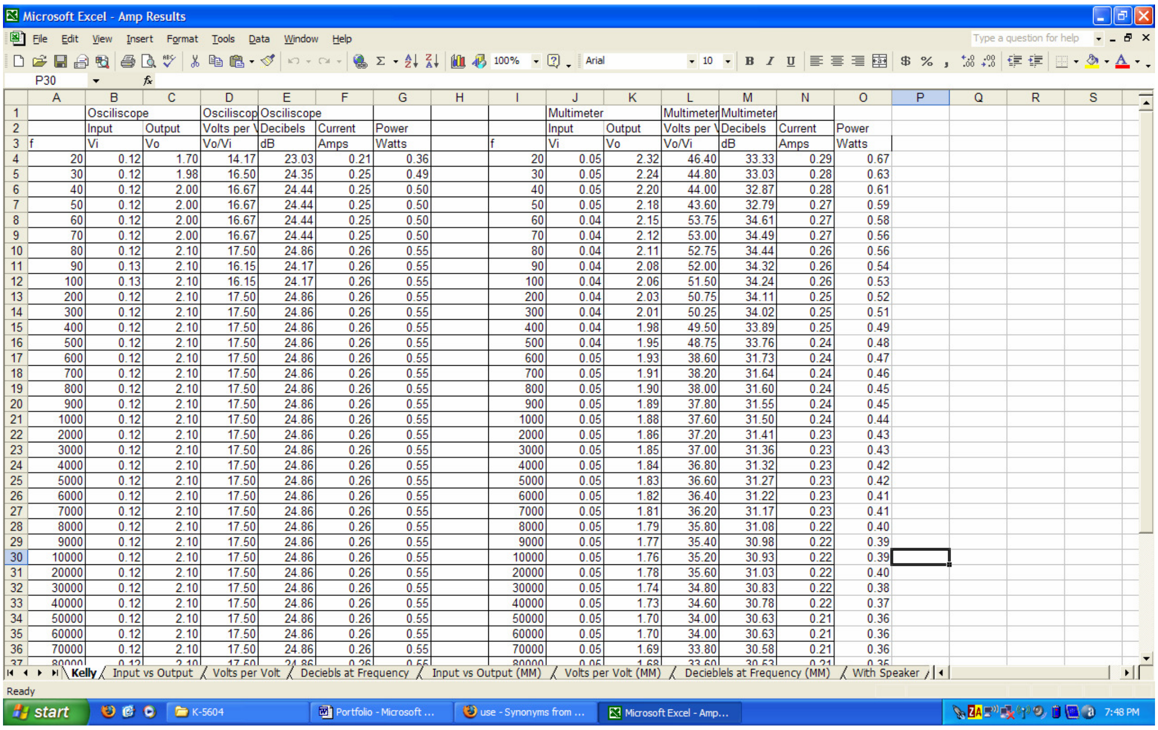


Figure 2 A threaded section of debate from “Fablusi”.

2.4 Use a computer to create spreadsheets and graphical outputs for reports.

During project two, part of my contribution entailed the collation of data from testing and formatting this data in a spreadsheet for presentation. This can be seen in section 3.2.3, pgs 9 – 13 and also below at Figure 3.



	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O
1		Osciliscope		Osciliscop	Osciliscope					Multimeter		Multimeter	Multimeter		
2		Input	Output	Volts per V	Decibels	Current	Power			Input	Output	Volts per V	Decibels	Current	Power
3	f	Vi	Vo	Vo/Vi	dB	Amps	Watts		f	Vi	Vo	Vo/Vi	dB	Amps	Watts
4	20	0.12	1.70	14.17	23.03	0.21	0.36		20	0.05	2.32	46.40	33.33	0.29	0.67
5	30	0.12	1.98	16.50	24.35	0.25	0.49		30	0.05	2.24	44.80	33.03	0.28	0.63
6	40	0.12	2.00	16.67	24.44	0.25	0.50		40	0.05	2.20	44.00	32.87	0.28	0.61
7	50	0.12	2.00	16.67	24.44	0.25	0.50		50	0.05	2.18	43.60	32.79	0.27	0.59
8	60	0.12	2.00	16.67	24.44	0.25	0.50		60	0.04	2.15	53.75	34.61	0.27	0.58
9	70	0.12	2.00	16.67	24.44	0.25	0.50		70	0.04	2.12	53.00	34.49	0.27	0.56
10	80	0.12	2.10	17.50	24.86	0.26	0.55		80	0.04	2.11	52.75	34.44	0.26	0.56
11	90	0.13	2.10	16.15	24.17	0.26	0.55		90	0.04	2.08	52.00	34.32	0.26	0.54
12	100	0.13	2.10	16.15	24.17	0.26	0.55		100	0.04	2.06	51.50	34.24	0.26	0.53
13	200	0.12	2.10	17.50	24.86	0.26	0.55		200	0.04	2.03	50.75	34.11	0.25	0.52
14	300	0.12	2.10	17.50	24.86	0.26	0.55		300	0.04	2.01	50.25	34.02	0.25	0.51
15	400	0.12	2.10	17.50	24.86	0.26	0.55		400	0.04	1.98	49.50	33.89	0.25	0.49
16	500	0.12	2.10	17.50	24.86	0.26	0.55		500	0.04	1.95	48.75	33.76	0.24	0.48
17	600	0.12	2.10	17.50	24.86	0.26	0.55		600	0.05	1.93	38.60	31.73	0.24	0.47
18	700	0.12	2.10	17.50	24.86	0.26	0.55		700	0.05	1.91	38.20	31.64	0.24	0.46
19	800	0.12	2.10	17.50	24.86	0.26	0.55		800	0.05	1.90	38.00	31.60	0.24	0.45
20	900	0.12	2.10	17.50	24.86	0.26	0.55		900	0.05	1.89	37.80	31.55	0.24	0.45
21	1000	0.12	2.10	17.50	24.86	0.26	0.55		1000	0.05	1.88	37.60	31.50	0.24	0.44
22	2000	0.12	2.10	17.50	24.86	0.26	0.55		2000	0.05	1.86	37.20	31.41	0.23	0.43
23	3000	0.12	2.10	17.50	24.86	0.26	0.55		3000	0.05	1.85	37.00	31.36	0.23	0.43
24	4000	0.12	2.10	17.50	24.86	0.26	0.55		4000	0.05	1.84	36.80	31.32	0.23	0.42
25	5000	0.12	2.10	17.50	24.86	0.26	0.55		5000	0.05	1.83	36.60	31.27	0.23	0.42
26	6000	0.12	2.10	17.50	24.86	0.26	0.55		6000	0.05	1.82	36.40	31.22	0.23	0.41
27	7000	0.12	2.10	17.50	24.86	0.26	0.55		7000	0.05	1.81	36.20	31.17	0.23	0.41
28	8000	0.12	2.10	17.50	24.86	0.26	0.55		8000	0.05	1.79	35.80	31.08	0.22	0.40
29	9000	0.12	2.10	17.50	24.86	0.26	0.55		9000	0.05	1.77	35.40	30.98	0.22	0.39
30	10000	0.12	2.10	17.50	24.86	0.26	0.55		10000	0.05	1.76	35.20	30.93	0.22	0.39
31	20000	0.12	2.10	17.50	24.86	0.26	0.55		20000	0.05	1.78	35.60	31.03	0.22	0.40
32	30000	0.12	2.10	17.50	24.86	0.26	0.55		30000	0.05	1.74	34.80	30.83	0.22	0.38
33	40000	0.12	2.10	17.50	24.86	0.26	0.55		40000	0.05	1.73	34.60	30.78	0.22	0.37
34	50000	0.12	2.10	17.50	24.86	0.26	0.55		50000	0.05	1.70	34.00	30.63	0.21	0.36
35	60000	0.12	2.10	17.50	24.86	0.26	0.55		60000	0.05	1.70	34.00	30.63	0.21	0.36
36	70000	0.12	2.10	17.50	24.86	0.26	0.55		70000	0.05	1.69	33.80	30.58	0.21	0.36
37	80000	0.12	2.10	17.50	24.86	0.26	0.55		80000	0.05	1.68	33.60	30.53	0.21	0.35

Figure 3 A segment of an Excel spreadsheet used for report 2 (section 3.2).

2.5 Demonstrate an awareness of general electrical safety standards.

Week 1 of semester, Monday 27th February 2006 at 2:25pm, our group spent time reviewing safety standards for the time we were to spend in the laboratory. The document discussed can be seen at 6.3.

After this review, much time was spent during the first week in the laboratory soldering our first project, the Robot. Time spent during this week was often supervised to ensure adherence to safety standards. The timetable of week one classes including the Occupational Health and Safety session are shown at section 6.4

During semester, I was not injured in anyway and incurred no difficulties in the laboratory due to safety.

2.6 Demonstrate an understanding of the social and technical roles of a professional engineering.

As with any job, a full understanding of the roles performed by a professional engineer will not be fully understood until a person has spent a considerable amount of time in the workplace. To assist students appreciate the varied responsibilities of an engineer, the website Fablusi was used as a forum for open debate in the context of a role play set in boardroom. Different characters expressing mixed opinions were selected by team members who then were required to discuss the pros and cons of solar energy depending on the character profile chosen. A transcript of the messages posted can be seen at section 6.2. This debate explored a variety of possible factors involved in implementing a new project including the environment, public opinion, cost, political consequences and so on.

The technical aspect of an engineers position has been constantly explored during PBL as each project is broken down into each component. Research, construction and testing were all anticipated functions of an engineer's occupation, however many people, myself included, were surprised at the level of communication necessary to perform common tasks. This has been a major component in PBL and work in this area can be seen in section 3.0 and continually in section 6.0. This has included written and oral communication, research skills and team work.

2.7 Demonstrate an awareness of the uncertain nature of some engineering designs.

The aim of project two was to test a set circuit for it's characteristics to see if they met those specified with the circuit. While five circuits were built by out team, only one was successfully tested as the other four did not provide a working set of results. This was in spite of the fact that all five circuits were created from the same kit, from the same manufacturer. When the working kit was tested, it was discovered that it did not meet the specifications listed. This demonstrated to us that despite the standard circuit, the output of the circuit can vary from each kit. (See section 3.2.3)

Project three presented the team with a number of graphs that we were able to compare with expected outcomes found on the internet (section 3.3.3 and 6.5). The differences, although slight illustrated the varied responses that are to be expected when testing any design.

2.8 Communicate to professionals and non-professionals the fundamentals of the "language of engineering".

Communication is a major aspect of any form of study. PBL was no exception and, in fact focused on this area. Weekly meetings with our team members and supervisor involved the use of technical language and discussion when conferring on current projects.

All reports were written using formal language while explaining all technical components researched. This can be seen in section 3.2.3 and 3.3.3.

Talks presented in the last weeks of each project also used formal language and explained the contribution made by each team member towards the project. These were presented in front of our Technical and English Supervisors as well as the other teams in our group. The detail in explanations, therefore, varied to account for the mixed audience. The allotted time for these talks limited the extent of detail that could be delved into however, so the presentations may have proved difficult to understand for the lay person. The full transcript of my section of the talk along with the slides used can be seen at 3.2.2 and 3.3.2.

2.9 Locate, evaluate, manage and utilize critically information for a range of purposes.

For both reports two and three, a great of research was undertaken to see each project complete. In both cases, our team focused on the research component as we desired to know more about what we were dealing with than to spend time dabbling with components we did not yet understand.

Due to the mass of information that was available to us via books, journals and the internet, it often proved difficult to determine which were the most appropriate sources to use and, in the case of contradiction, which source was the most reliable. The majority of my research was taken from the internet as this proved to be the most up-to-date information source available to me. Generally, information from science journals showed themselves to be far too technical and focused on a very specific aspect of a topic and therefore, inappropriate for our purposes. Books were occasionally used but were often quite outdated and became a secondary source rather than being the first place we looked.

6.2: Theo's portfolio - Semester 1:

1.0 INTRODUCTION

This semester, we were given the chance to find and improve our generic engineering skills and the ability to work effectively as a team. Generic skills, such as the ability to locate and interpret information such that it can be easily communicated to either engineering or non-engineering professions.

This portfolio will attempt to show what skills I have gained and the achievements that followed during this semester. I have drawn from some of the pieces of work I have written and discoveries I have made during the course of semester 1 and I have used them to support my claims for the various learning outcomes, such as technical knowledge and word processing abilities.

2.0 LEARNING OUTCOMES

2.1 Demonstrate the successful completion of a project(s) in a specified time period.

The first project this semester is a fine example of proper time management and the completion of a project in the designated time period. We were given time over our first week to construct our robot kits. With the robot, we were to write a short introduction and hand them to our team supervisors. Even though my first week was complicated as I had to balance work with construction time, I still managed to complete all the deliverables on time by spending extra hours in the laboratories devoted to construction. The robot and report were handed in on the designated due dates.

2.2 Demonstrate professional engineering skills.

Throughout projects one, two and three, I have been given the chance to learn and display knowledge of certain science and engineering fundamentals such as soldering, circuit design and theoretical knowledge. One example of this is shown in Appendix A which is taken from my slideshow for problem three's presentation. Here I am displaying theoretical knowledge by applying watt to kilowatt hour conversion to the power output of our solar panel.

2.3 Use a computer to perform word processing as a communications tool.

For every report and presentation done this semester, I have used my computer to perform word processing and slideshow presentations. I am submitting a small excerpt from my reflective piece for problem two as an example of word processing (Appendix B).

2.4 Use a computer to create spreadsheets and graphical outputs for reports.

One example of a graphical output is taken from my oral presentation for problem three (Appendix C). I gathered information on the average household power usage from the USA, Australasia and Europe. Converting it into a graph from this point was rather simple as there were only a small amount of variables that needed to be taken into account.

2.5 Demonstrate an awareness of general electrical safety standards.

During my first week, I was required to attend a laboratory health and safety session. At the session, laboratory safety manuals were handed out to each student present. We were asked to read through the document and sign to show we understood the rules in place before we could take any active part in laboratory sessions. Safety precautions such as protective clothing, hazard awareness, material disposal, cleanliness and building evacuation plans were covered at this session.

2.6 Demonstrate an understanding of the social and technical roles of a professional engineer.

Engineers are usually seen to be socially inept with a very naive view of politics. The modern day engineer however is required to have better social skills and a in depth outlook on the social impact of their designs. The work we did, particularly in the third problem, gave us the opportunity to demonstrate an understanding of the impact of our problem designs on the outside world. We also had the chance to present our solutions to a small audience on two occasions.

2.7 Demonstrate an awareness of the uncertain nature of some engineering designs.

This is particularly relevant to problem 2. We were given an amplifier and told to research how it works and test it. At first we didn't know how it worked, but given time and experimentation, we managed to gain a fair understanding of it's operational role.

2.8 Communicate to professionals and non-professionals the fundamentals of the "language of engineering".

On two occasions we were given the opportunity to communicate to professionals and non-professionals in the form of an oral presentation. Attached (Appendix D) is an assessment sheet for my first oral presentation. It shows that I have the communication skills an engineer requires. I also had the chance to improve upon any problems I may have had in my second oral presentation.

2.9 Locate, evaluate, manage and utilize critically information for a range of purposes.

Throughout the semester, I have been given the chance to search for information relevant to our problems and pass it along to the rest of the team. Appendix E is just one example of the results of searching for information regarding testing techniques for amplifiers. This was only the first step though, after the information was found, it was suggested that I summaries the relevant information found on the webpages so that my team-mates can easily understand the information I have given them. Also, when doing research, I would make good use of the email system setup for the students to also email myself discovered information so I can access it quickly and easily from either home or university.

Appendix 7 The lift controller problem document

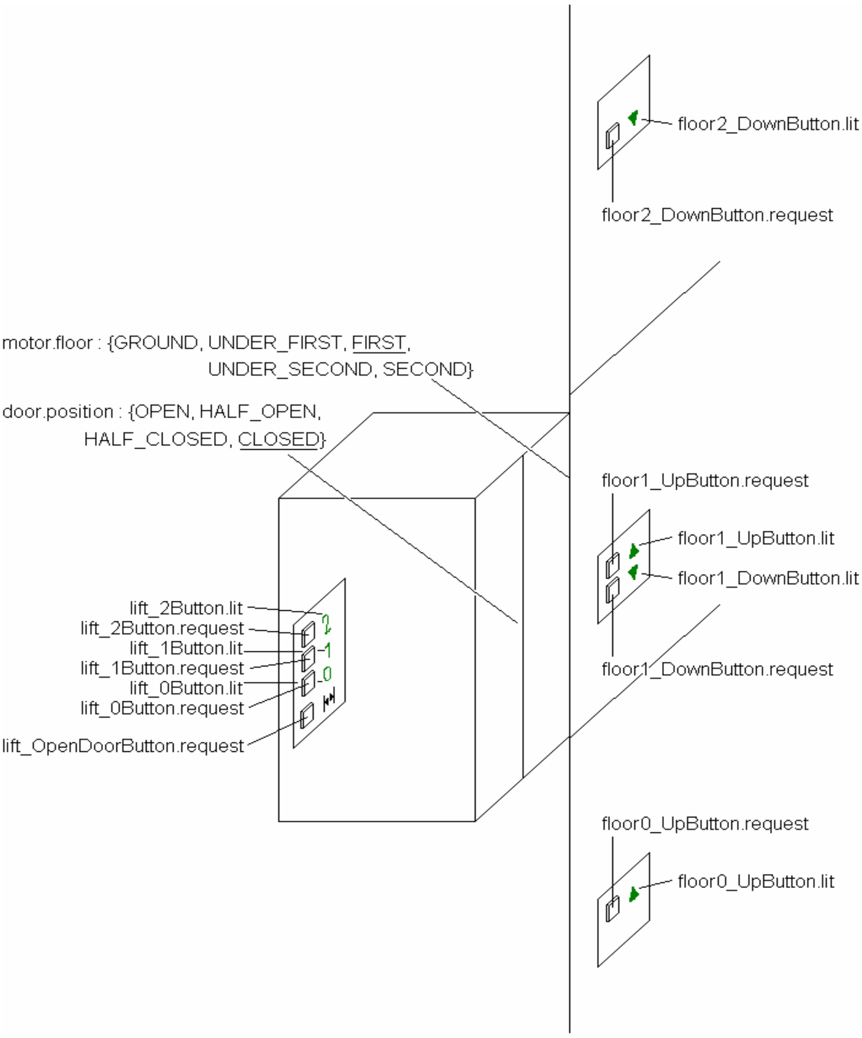
The Lift Controller

Purpose
The purpose of this group task is to find out,

- How do you go about problem solving?
- What are your skills in working together?
- What engineering and other knowledge do you use?

Overview
You have been hired by Victoria University to come up with an idea to design an advanced lift controller system that brings significant commercial, technological and operational benefits to the lift industry in terms of reliability, cost saving and ride quality.

The Lift
The lift in the focus of this activity serves three floors. You need to consider the controller, as well as the necessary sensors and actuators to operate the lift. Its controller responds to requests from a panel of buttons inside the lift – where *requests* for floors are made and where a call to open the door can be made – and from a panel on each floor – where the lift can be *called* with the intention of going up or down. The controller defines a *mode* – whether the lift is *going up* or *going down* or otherwise is passive and waiting for a new call. It also sends messages to two actuators, one controlling the door, the other the lift motor. Each of these actuators provides feedback to the controller: in the former case on the position of the lift, in the latter the position of the door. The following diagram provides an intuition about the lift under consideration.



Task

You are required to,

- As a group discuss the problem and brainstorm ideas
- As a group decide what ways you'll get the information needed and share the information to formulate and suggest possible innovative designs to solve this problem (need not be the complete solution – just ideas)

You are reminded that you have just 1 hour to complete this task.

Resources:

- World Wide Web (e.g. www.howstuffworks.com)
- Library online
- Books provided by the researcher

Appendix 8 Examples of audio transcript

8.1 Focus group interview with Bruce and Phillip in Semester 2

Introduction
Formalities

How do you approach problem solving?
This problem? Yeah well, this semester, we got our problem and the group brainstormed a whole bunch of ideas about the problem and then we just delegated all the sections of the problem to different people. So that's pretty much the first thing we do. Yeah and then tell like all the different people assigned different parts to research their section of the problem and then just run our weekly meeting which will go about an hour just like elaborate on what they have found.
So it is pretty much individual so you go and do your own research come back and talk about it in the group meeting.
Apart from when the two individual parts cross. Because for instance, Lachlan was doing the traffic lights in Boreland and I was doing a bit also on Boreland, so once he finished the traffic light, we got our two solutions of Boreland and put them together to make like a really, really good solution to that problem, so sometimes they cross over and we have to talk about stuff.
So you do your individual task and then choose the best one out of it.
Yeah, Yeah. But for those people that have individual task. But that doesn't cross over.
I also understand that your group has changed from the last semester and you are working with new people. Especially you have massive amount of people in your group. How do you cope with that?
I guess, I just put it on my schedule. I got a little calendar thing. We had to think about lot more tasks this time for all the different people. I guess it was last week the progress report on Friday was due and I told everyone to give it in by Tuesday and half the group handed it on Tuesday and half handed it on Thursday. It is harder to manage more people but, it's good because you get better quality, because you get more people doing more work and stuff.
What about you Phillip? How do you approach problem solving?
Well, I probably do things like last semester. i just, with the problem we delegate different aspects of it. Like different section. For example I was given the part the digital side while everyone else is researching the programming bits and stuff and how to improve it. So, mainly for me, how I tackled it? um, well. I basically, this time for me, sorry. I had to do a bit more research on this one because this is the first time that I am doing something on the digital side. So, I had to actually learn a lot more this time compared to last semester, I was given a lot of topics on the money side of it or costing and I knew a lot about it, so I didn't have to do as much research. But this time, I had to do a lot more research because it’s pretty much new to me.
Do you learning more from it?
To some extent, yeah I am actually learning a lot more, because of that I had to do a lot more to actually finish my part of the problem.
Whom do you approach if you have difficulties in understanding?

Personally, I haven't asked anybody yet. Because I still got like, you got lecture notes from [lecture-based subject teacher]. He teaches the digital side so, a lot of the notes he writes on the board so that I can actually refer to and stuff like that for example, logic gates which this topic would probably consist of. I can actually look on the notes that I did last semester and just have a look on the notes and see how logic gates work and stuff and this semester we are doing the clocks and stuff, the different pulse and stuff. So, because of that, I can actually refer to that in the problem. So, when I look it up on the internet for example the topics about how it works, and it actually says how it works how it affects the traffic lights for example. I need to know about the traffic lights, so because of that I can actually put all those stuff together and figure out how to do it.
Bruce: I got the same with the programming in Boreland; I didn't really know much about the software at all. So, when I got stuck on plan and stuff, I read the help file a bit and then when I got really stuck, I went to [lecture-based subject teacher] as well and he helped me as well with the while loop and yeah. So he helped a bit.
How do you approach your supervisor? You have a different supervisor from your previous semester.
No, we have [PBL supervisor] this semester. I guess everyone is finding him a bit different to [Semester 1 PBL supervisor].
How does he help with your queries?
Yeah, he has done. When we first got the problem he showed us a solution to the problem in the software side of it. Yeah he showed us a solution. Just not any of the code, but just the visual on what he was expecting and stuff. We haven't gone to him that much this semester because [laughs]
Has he helped your learning in anyway?
Bruce: No
Phillip: some extent. he does put a lot more input in the meetings, like he does a lot of talking in the meetings so, he does actually say some things like for example, like how to tackle certain things, how to do different coding and stuff like that. Like he does give us some hints and stuff like how to do it. But for me the only thing is it is not really. He goes to some extent a bit a spoon feeding if you know what I mean.
So he sort of goes to a bit of spoon feeding is it?
Yeah, you can sense a bit of spoon feeding. Because he is basically telling us what to do almost.
He is not letting you take responsibility?
Phillip: yes
Bruce: May be because he is new to this, because he is
What responsibilities do you take in your group and why do you take them?
Phillip: What are my responsibilities! I take the minutes in the meeting and the reason why I took it like. I took it at start, the first meeting we had, I took the minutes and all that and because I had like a system setup at home already, I decided to continue on with it, because I had already all the minutes done up. Just might as well continue with it, so, because I was used to doing it quite few years ago, when I used to do, because we used to have like, in high school, we used to do something similar and I usually took all the notes and stuff, so, I was kinda used to it. That was the reason why I took the minutes really.
Bruce: After we brainstormed all the ideas and stuff, I thought I want a challenging task in the problem, So I took on the Boreland simulation software and how to go about and also the statistics of the intersection. I was taking on two sections of it. To do this statistics, I video taped the intersection and played it back, which was pretty

helpful. I had made an agenda template last semester for the team agenda every week so, yeah I do that. I am still doing the agenda and
So you two do most of the stuff in your team basically. What about the rest of them?
Bruce: I don’t know. During the meeting I set the due dates, because you don't want everyone handing it on the actual due date so, I made everyone hand it in on Tuesday.
So are you leading the group are you?
I wouldn't say leading, but yeah sort of, and I got everyone's part to the progress report and put it all together.
You are doing work similar to what you did last semester. You are doing the compiling work.
yeah. Pretty much. I compile work and also my bit. The other guys, Lachlan and Jacob are helping a bit with Boreland. Which is a good help and Alex and Sanjay are totally doing different to what we are doing. They are doing
Phillip: Improvements
Bruce: Yeah other ways to help the traffic lights cope with the traffic like lasers and stuff in the road. We just delegated them to the task of researching different ways on how to improve the traffic lights.
How do you think those guys are progressing?
Yeah, they have sent pretty good stuff to say in the oral and I read their part of the progress report because I compiled it and they sound like pretty switched on and they know what they are doing.
What generic skills are you learning?
Bruce: I don't know. May be it will be the leadership skills and managing a bigger group, because this is the biggest group that I have ever sort of managed. And also talking to people about a common problem like me Rodney and Adrian, we were all doing Boreland so, we all had like our mini meeting and stuff and then I sent Rodney part of my solution and then he sent me part of his solution and now we have got really good solution and we've just got one more thing to do and its gone pretty good.
Phillip: I probably improving on in this semester is my research capabilities like, with this topic, i have to do a lot more research so, and I have to try and get it as quick as possible so, I have to actually delegate a lot more on, not delegate, sort through a lot more information and I am not used to. So I am kinda learning how to do that more quickly. But apart from that, I know how to do oral presentations; I know how to do reports so. I can't really improve much on it, if you know what I mean. Apart from that there is not much that I done that’s, how to say, skills, yeah?
How much time do you spend with your group and where do you meet?
Bruce: As you know we meet once a week as a group at 4 o'clock up here every week with our supervisor, but for instance on the second week or the first week when we were delegating task and nobody really knew what they were doing, we had an extra meeting on Thursday or Friday without our supervisor, just to get in our head what every is doing. Just to get a bit more organised and me and Rodney has had one on one discussion over msn at our houses and stuff.
So you use msn is it?
Yeah, MSN live chat to send information and stuff.
How much time do you meet in a week.
Couple of hours. Like because, me and Phillip we have got the same classes so we talk about the problem for about an hour or two together.

8.2 Individual interview with Matt in Semester 2

What do you feel about participating in the Problem solving activity?
Nothing actually. It's kind of second nature now, the way to hit at the problem.
Did studying in PBL curriculum help you understand how to go about problem solving?
Yeah, yeah. Yes very much. Its the same way with all learning. Because you have done a flow, I have done it, like there were three problems in the first semester I think and the one big one in the second semester. So I have done it four times before and I sort of know the steps to take to solve the problem yeah.
One more thing I wanted to ask you was your part as a producer of the PBL party video.
Yes what about it?
Why did you guys come up with that idea?
[Laughs] We had an oral presentation and we couldn't be bothered studying. So we decided to just report the random stuff and then it became that.
So you actually presented that video in your oral presentation?
Yeah. Well we figured also, my theory is especially when you know who your examiner some one like is [supervisor] who sort of likes fun. If you can make some one laugh, you have got more chance, like make them happy and enjoy the presentation and you have more chances of getting a better grade anyway. Or people are going to take back more from the presentation because they are paying attention. So why not, so if you can just show it and the worst case scenario is that they don't mark it. Best case scenario is they look more closely at our presentation and will feel more confident with that presentation because of the video and then mark as well.
So was the video was intended to create a fun environment or was it to demonstrate team work or something like that?
We did something like that, we started off like, we did have like six hours or something [to wait before the presentation] so then we were like nah, lets just do something and then we realised that we could actually use this for our presentation so we did.

What sort of editing equipments did you use?
I just used my laptop. I have done editing heaps of times before.
What sort of software was that?
I think I used windows media for that one, because I have never really used that before on laptop and well it's kind of once you have done for something else its makes it easy. so I used the windows movie or what ever it was. Nothing professional with that one.
That video sort of created controversies later on. But before that it was on WebCT for sometime.
Who posted it on WecCT? Did you guys post it or did your supervisor post it or?
Our supervisor posted it on WebCT as well as on YouTube.
What is your understanding of PBL now? What do you think PBL is?
Redefine the question.
I have been asking you about what was your understanding of PBL before and I wanted to know how you perceive that now.
Well now I don't just see it as something that was used to create practical skills or some way to furnish us with practical skills. Like, I see it is a learning process that teaches you to learn, I think now, more than anything and it gives you the skill you

require to address a problem. Once you are given a problem to address it and trying to solve it with the best of your abilities. It teaches you how to solve a problem really. I think that sums up the best.
What is your understanding of the generic skills now?
Same as before really, it is just skills like writing skills just all the basic skills that you need to function normally. That is sort of improved.
How does a learning generic skill help you as an Engineer?
Well there is no point, for starters there is no point if you are a genius but you can't really express. Because what ever you could speak will be stuffed. Because you learn generic skills, you know how to use a little key board thing, so that you could talk, you know he could express the rest of his knowledge to the universe after he became sort of paralysed and everything. Otherwise you would have had only up until u became really crippled by decease. Because you learnt generic skills like how to use his key board we know. Communication is what I am getting up, if i have an awesome idea but i can't communicate just can't communicate, what is the point? its rubbish. Its going to get discarded and it is a loss to humanity.
Having completed two semesters of PBL now how do feel about sharing your point in the group meetings?
I just do it now. I don't care coz if I don't do it now I won't. That's my experience so far. So I might as well give my own value and then I know I am justified. Because if not yeah.
What was your contribution to your group this semester?
Everything.
Pretty much everything?
Yeah
What did you do? Everything?
Well, I designed a program and I designed a second program of the first program, I wrote the programs, I edited the programs, I perfected the second program and then I, we, me and Luke started to design for the logic and control and we designed it. We spent the whole time designing and then we finally got finished design. Then we started a little bit of construction but we decided the other guys needed something to do coz then have done nothing. So we assigned them construction. We basically did the problem, we solved it.
How do you say that your group worked well as a team/
It didn't. It did, but no one ever did any thing, we do everything properly like me and Luke had we had the regular meeting me and Luke will meet up in here in the academic centre, every couple of nights or when ever we wanted to work something out. And we post like on WebCT that we are going to help you guys out or what do u want to do? They never did anyway so we always we just basically backed realised just to say but do it ourselves, because we know they are not going to do it anyway. So we tell them to and just do it ourselves. It was the same as last semester, two people in the group me and someone else in the team could work and the rest just kind of didn't care.
It was you and Edward last time wasn't it.
Yeah, and then Edward got with some more friends and decided, he just couldn't be asked. So then it was just me and Luke.
Do you know he is repeating PBL this summer?
Yeah, I guessed. Because I know that he can't have a pass.

If you had a chance to rewind the clock and go back to the beginning of the second semester what would you really want to change in your group? Or what would you want to improve?
I wouldn't really improve anything; everything went so well for the design, because I and Luke worked so well together. I basically keep me and Luke and I would pick three other members. Basically I would cut off the other four and input two new ones instead and would just have a small group of four. By then it is already double the thinking capacity people load and that, yeah.
Did you approach your supervisor about the problem in your group to your supervisor?
Sort of but they picked it up themselves. But there is not much they can do, you are in uni now all that they can do is say, it is not much the difference it happens.
Not much who can do? Are you talking about the supervisors or the students?
Supervisors or the students, like you can say to the supervisors, I think we went to him once may be. But still all that they can say is: you know you are going to fail if you don't do it. That's all they ended up doing. It's based on, your assessment is based on what you contributed not what the group has done. So you just keep going is all [supervisor name] said all semester. Just keep doing because it is your assessment. You are assessed on what you, you will be at a, teach yourself lot better on all the learning outcomes when you did all the work. So it was like cheer you to do that.
What did you do to make your group work together?
We talked, we did the regular meetings [meetings with supervisor] posted stuff on WebCT, messaged, rang. But they just even show up to the meetings, so when, it was just me and Luke worked basically we just used white boards and nutted out ideas.
How did you think WebCT helped your learning?
Got PBL party up. It didn't really; it was kind of pretty pointless this semester. It didn't really do anything. Like it would be very useful if, but me and Luke both live here.
So this sort of became your PBL studio?
Yeah.
When was the PBL studios available to you?
It took like seven weeks after the start of semester or something. It was ridiculous. We got them for the last five weeks I think, they were great when we had them. It was bull crap when we hadn't the rooms.
Did that sort of create any problems for the group meeting together?
I don't think, I think it can't be helped, but it was something that didn't help the situation. I think that was individuals not the school's or not having the suites or.
How did you approach a particular task say for example, programming or designing? What sort of resources did you use? Where did you go and find the information?
The internet can be a great source I have learnt. But there is also a lot of rubbish. So I basically do a general kinda of search on the internet and then look through books and then talk to people. That's basically how it went and also read books. That's the main one.
Whom do you talk to?
Other people I know, Have experience in this area or like the supervisor or just people like Siva. People like that, just randomly people I know what they are talking about the information. And also I found that it was good to question your work like get other, get Luke to, like I get him to see something that I didn't see something. We get each other to show. That's how we knocked out lot of the problems that we had. He was like, Mate I don't get it, well it is easy and then he would go like I don't get it.

And then eventually like I will be wrong somewhere, there is a mistake, he is right. And then the same vice versa, he would be like nah, we would realise that we had done a mistake.
So you and Luke did most of the work together?
Yeah. Ok.
How did you find the Library? Was that of any help?
It was alright. It was better than the internet. It is just, I am not, when I find the right book, I am good with books. It's just I have to find that book. Basically, I already had the books that I needed. I had already purchased them everyone, just used them a lot more than, we found one book, the book you lend me and Luke. Actually I have got that book for you. That book you lend Luke is a good one. It's just when I find the resource, the library has got them, and you just got to find them. And as long as Siva has not already borrowed them out from the library [Giggles]. First place they should be available.
How did you go about the support classes?
I had to work so I couldn't go. It was either go to support classes and learn a lot, but then I had to drop out of uni, because I couldn't afford to pay much for my rent it was work full time on Mondays at a factory. So I choose to work fulltime on Mondays at a factory and continue my studies.
So it was pretty much on Mondays that you had the support classes.
It was only Mondays that we had our support classes.
Because I have heard the rest of them say that the group got [support lecturer names] to get some help.
I just met lecturers individually when ever I had a chance, when ever they were available. Personally rather than going to the support classes, coz I did have the option.
Did you go and speak to your supervisor about any problem that you might have had?
Not about PBL, not about in general the course I did.
Did you approach your supervisor or anybody in terms of understanding a particular subject or topic that you had difficulty with?
Not really, it was more abstract this semester. It was just basically PBL meetings with the supervisor this semester.
I didn't go the support person at all, because he wasn't available to me. Like there was no support person for me because it was only Mondays.
What other disciplines have you looked at while problem solving this semester other than electrical engineering?
Well, I suppose most of them come under that. What did we look at, we looked at the what are they called, the accident commission or whatever it is. I don't know what discipline that comes under. We looked at that; we looked at some traffic automation stuff that’s still engineering it think, even if it is still.
I think they were all sort of engineering basically.
How did you go about doing the survey? Did you know how to do a survey or were you taught how to do a survey?
We didn't, we basically wanted one that was mainly because of convenience and one that definitely looked like it could be solved, so we actually just, we went all over Footscray area, Ballarat road all the way down to the station and the whole area and just basically looked at them all to see how they worked and interacted and the Ballarat road was perfect, build up was massive on the Ballarat side. So if we could go with it, it was close, it was easy to analyse, which gives us more time to analyse data we can actually go backwards and forward from uni effectively from the

intersection, that was it and then actually analysed the intersection just as easy as a person each corner counting time for a set period and collaborate ourselves.
This question is about peer assessment and self evaluation which you have done in your portfolio. How do you think that would have helped you or your team achieve the marks that you have achieved? How do you think it helped your supervisor in assessing your team?
Because everyone is doing the same thing and generally speaking most of them will be someway honest. May be not about themselves but they will be more honest about everyone else, so if you've got say in our group there was five members left in the end. Five members talking about other members so you have got four evaluations per person, so there is four evaluations of me including my own, but my own can't really be used as much, can be just used to confirm what you referred or denied. The other four would be sort of; it's like an average, the law of averages. That sort of average will give you a general idea about that person is like. So I think it would influence. It will confirm or deny what the supervisor would generally suspect anyway judging by the rest of the portfolio and what they have seen through out the semester. It is pretty easy to tell who, just by in the meetings who know what they are talking about and who doesn't, who contributes in the meeting and who doesn't.
So do you think that self evaluation and peer evaluation is important?
I think it help finalise the fact that, we have to evaluate other people through out our lives anyway. So it part of the learning process. You need to know how to evaluate someone. Like my mum she gets to evaluate all the time and she gets evaluated by other people. It is just part of life, but it also helps to police PBL. Like it gives the supervisor the extra knowledge, it confirms that they believe or deny.

Appendix 9 Examples of matrices and diagrams generated during data analysis

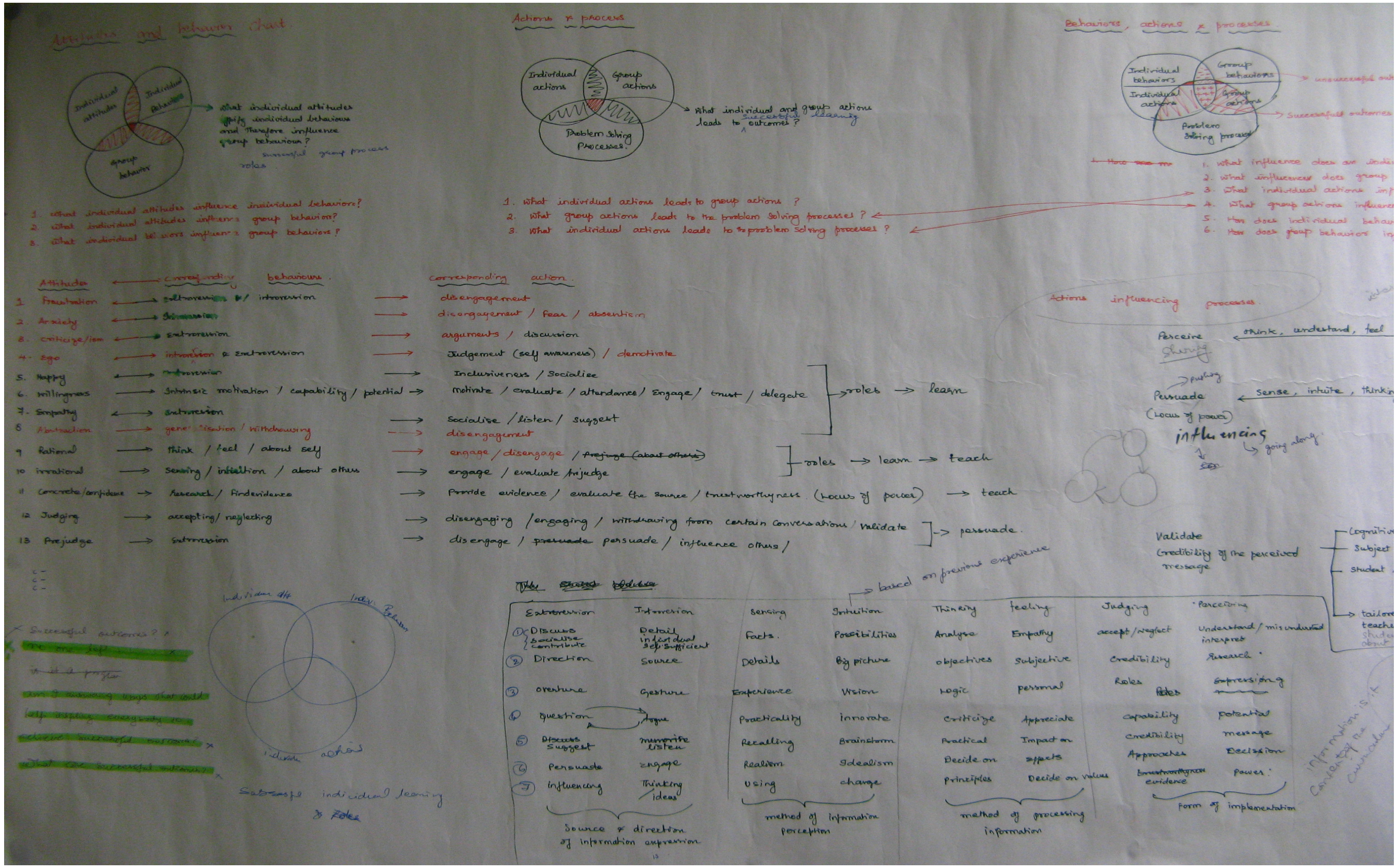


Figure A1 The analysis of attitudes and behaviour of students

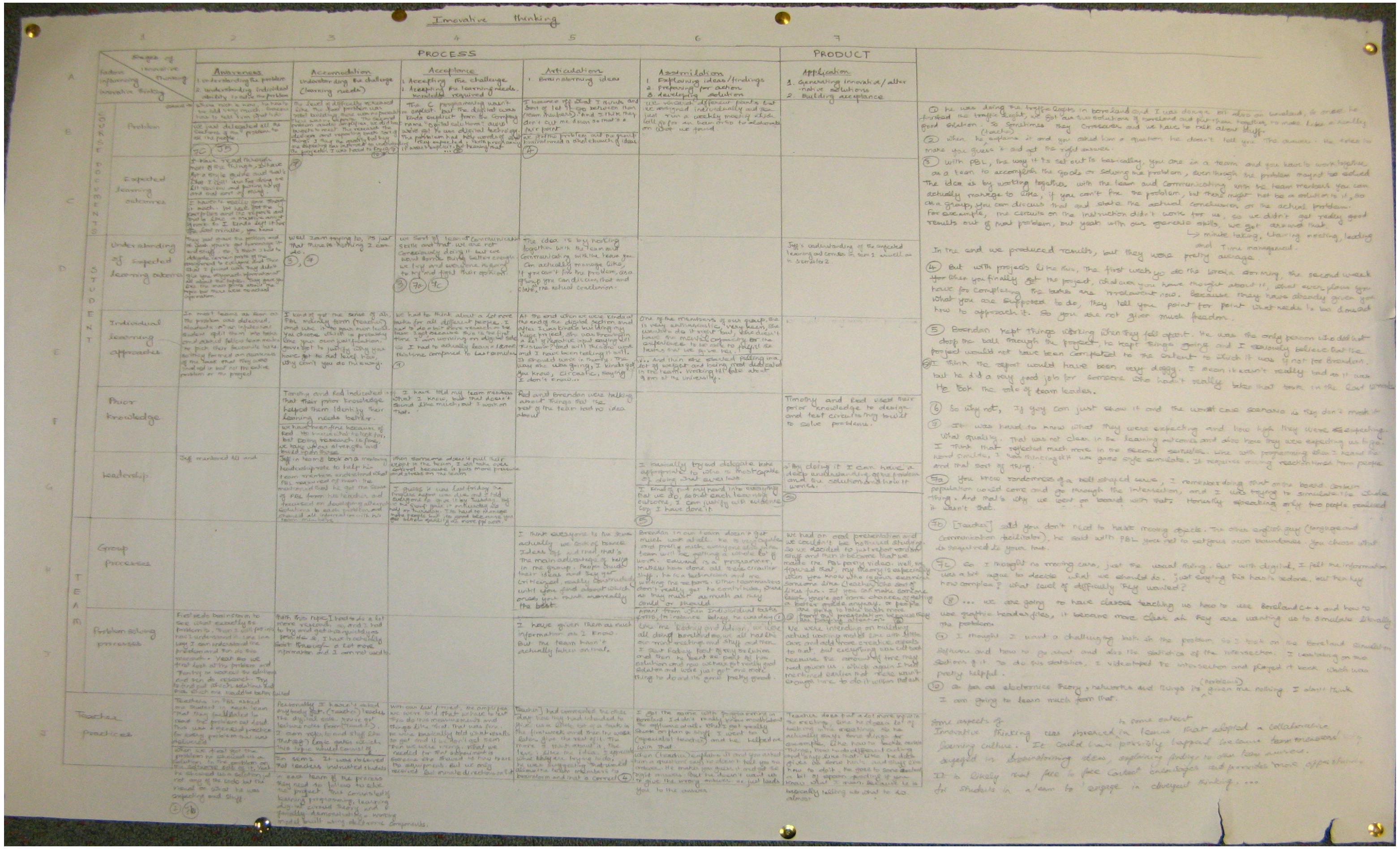


Figure A2 A matrix of stages of innovative thinking

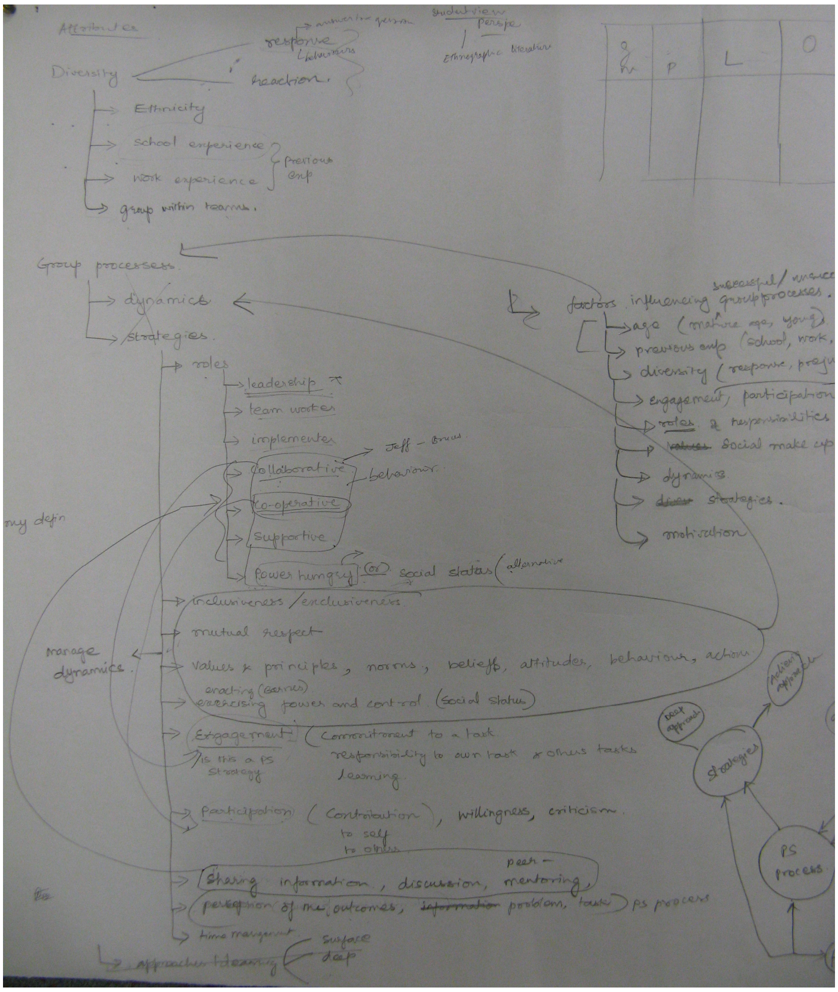


Figure A3 Categories of the factors influencing successful group processes

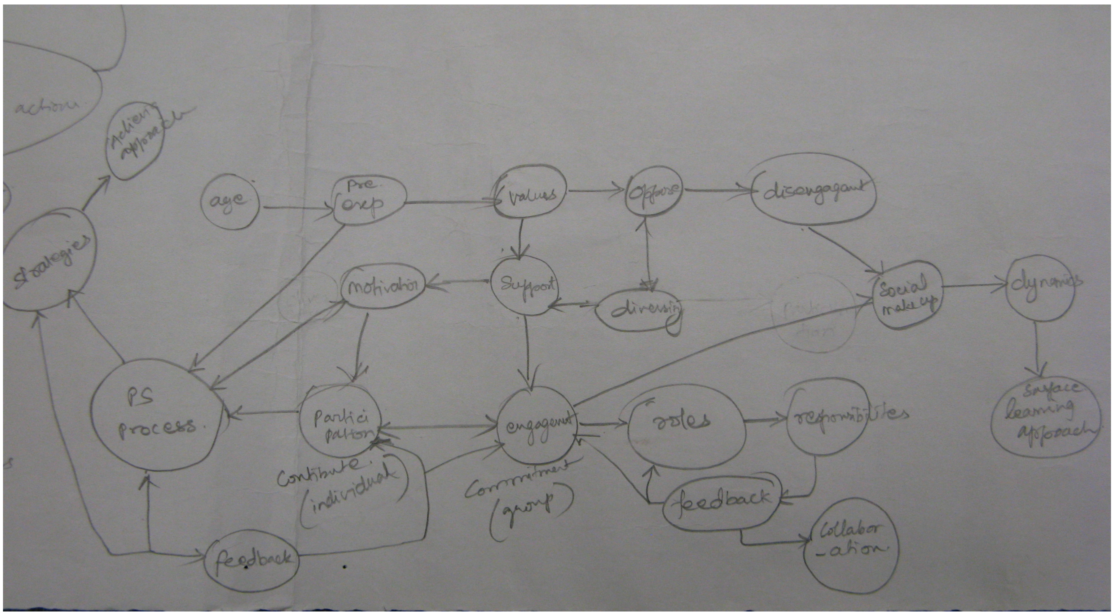


Figure A4 Connecting codes to identify factors that influenced a team's success

Appendix 10 Summary table of the characteristics of twelve PBL students

Students	**Background**	**Main reason for joining the course**	**Focus**	**Understanding of PBL**	**Activities Engaged**	**Examples of resources used**	**Tasks preferred**	**Roles**	**Learning approaches**
Edward	School-leaver	Family pressure, way of life	Aspired to make new friends and find his life partner	Developing language skill	Supporting other team members and soldering components to the circuit board.	Lecture notes	Helping the team, being instructed, practical work	Helper, but slowly transformed into a freeloader	Surface approach throughout the first year
Ali	School-leaver, attended university to maintain his social status, likes to have fun	Social motivation, an understanding that studying at a university is a norm among people of his age in his community	To become an electrical engineer in a specific field and obtaining a highly paid job	Managing problem solving, research, oral and written skills	Chairing meetings, negotiating with team members, research	Internet, books from the University's library	Research, leading the team	Socialising, wanted to be the team leader and always fought with another team member for that role	Surface approach throughout the first year
Jacob	Mature age student, introvert, has other family priorities	Family pressure, social reasons	Obtaining a highly paid job	Data was not collected	Completing individual tasks, writing his part in the technical report	Internet, computer laboratory	Computer programming	Did not take any consistent role. Mainly a freeloader	Surface approach throughout the first year

Summary table of the characteristics of twelve PBL students (continued)

Students	**Background**	**Main reason for joining the course**	**Focus**	**Understanding of PBL**	**Activities Engaged**	**Examples of resources used**	**Tasks preferred**	**Roles**	**Learning approaches**
Khadir	School-leaver, introverted and very silent	Area of interest	Achieve good grades and thus getting a good job	Research	Research, testing circuits and survey the intersection	Internet and books	Completing tasks individually	Spectator, mainly passive	Surface approach throughout the first year
Theo	Tertiary education experience, extroverted, cool and careless	Teacher's reference, fascination	Complete the course, completing the individual tasks and obtaining a rewarding career	Developing language, structured learning	Individual tasks assigned by other team members, did not contribute much in Semester 1. Research, designed timing circuit in Semester 2.	Internet, Laptop computer,	Information handling, communicating	Game player	Surface approach throughout the first year
Lucas	School-leaver, shy, serious, sensitive and very silent.	Data was not collected	Achieve high grades, find a reasonably good job	Data was not collected	Research	Internet, printer	Individual learning	Mainly passive	Surface approach throughout the first year

Summary table of the characteristics of twelve PBL students (continued)

Students	**Background**	**Main reason for joining the course**	**Focus**	**Understanding of PBL**	**Activities Engaged**	**Examples of resources used**	**Tasks preferred**	**Roles**	**Learning approaches**
Phillip	Tertiary education experience, silent, listener	Eagerness to learn new knowledge in the area of interest, employment	Supporting the team, making sure the work is done on time, getting a good job	Managing learning, managing team work, active learning.	Report writing, problem solving and thinking	Books mainly, did not have access to personal computer at home.	Research and practical work	Scribe, event manager, supporter and spectator.	Started off using deep approaches in the first semester but used surface approaches in the Second semester
Timothy	Mature age student, introverted, not so keen in making new friends.	Career aspirations and eagerness to become a specialist	Completing the degree to obtain a promotion in existing job, achieving high grades and becoming an expert in the field	Experiential learning, group learning and research	Chairing meetings, delegating tasks, asking questions of supervisors and leading the team	Books from library, Internet, electronic components manual, laboratory and teacher	Solving the entire problem individually, preferred to complete most tasks himself. Circuit design and testing in particular	Leader and mentor	Used surface approaches but focussed on a product that would maximise the chances of high grades

Summary table of the characteristics of twelve PBL students (continued)

Students	**Background**	**Main reason for joining the course**	**Focus**	**Understanding of PBL**	**Activities Engaged**	**Examples of resources used**	**Tasks preferred**	**Roles**	**Learning approaches**
Claire	Mature age student, extrovert, enjoys socialising.	Enthusiasm to learn new knowledge, doing things hands on	Learning and excel in the field of engineering, enhancing career prospects	Learning as a group with a diverse set of students with varied experience and skills	Chairing meeting, delegating tasks, planning, organising team work and leading the team	Used prior knowledge in most of the tasks that she engaged, Internet, books from the state library	Writing, collating team members solutions to individual tasks, experimenting.	Organiser, mentor and team manager, completer, admirer	Started off using deep approaches but focused on achieving a product in both semesters
Matt	Vocational experience, dedicated, extroverted and hard working	Educational motivation, job motivation, eagerness for new knowledge and personal interest.	Successful engineer, achieving a high grade by completing the problem thoroughly.	Experiential, experimental, active learning, student centred, structured learning	Organised group processes, problem solving, applying previous knowledge, discussing ideas with team members, socialising	Library books, University bar, laboratory, Internet and laptop computer	Problem solving, evaluating other team members ideas	Leader, organiser, mentor, evaluator, producer (PBL party video)	Started off using deep approaches but focussed on a thoroughly completed product

Summary table of the characteristics of twelve PBL students (continued)

Students	**Background**	**Main reason for joining the course**	**Focus**	**Understanding of PBL**	**Activities Engaged**	**Examples of resources used**	**Tasks preferred**	**Roles**	**Learning approaches**
Bruce	Tertiary education experience, committed to learning new knowledge	Eagerness to learn new knowledge in an area of interest, previous educational experience, family motivation	To become a specialist engineer in the field of robotics engineering	Unguided, student centred, self directed, practical learning	Chairing meetings, organising tasks and team work, delegating tasks to team members and leading the team	Laptop computer, lecture notes, Internet, books and teacher.	Information research, discussing ideas with team members and leading the team	Scribe, chair, leader, team worker and team manager	Consistently used deep approaches in both semesters
Jeff	School-leaver, keen on gaining new knowledge	Job motivation, Employability	High paid job, high academic achievement, become an expert.	Team work and collaboration. Self directed, independent learning environment where technical skills are learnt in conjunction with generic skills.	Brainstorming, discussing and sharing ideas, organising tasks, sharing knowledge and leading the team	Internet, books, manuals from the University library, lecture notes, teacher and laboratory	Researching information, discussing with team members and actively contributing to the team's work.	Leader, contributor, innovator mentor and shaper.	Consistently used deep approaches throughout both semesters

Appendix 11 Summary table of the characteristics of eight PBL teams

	Membership	Group processes	Team leadership	Learning approaches	Group learning & Outcomes	Productivity	Learning culture
Team 1	5 Students – Sem 1. 5 Students (including 2 new students) – Sem 2 Mixed ethnicity Local & International students Diverse school experience Same age group	Students formed groups within the team, lack of respect for other students, team work was constantly interrupted and students contributed to self-selected individual tasks. No co-ordination. No effective group processes	Leadership was seen a powerful role and students competed for authority. There were more than 1 student leading the team at a given time.	All students had surface motive and aimed at completing individual tasks. Used surface learning strategies and focussed towards passing the subject. Students rarely engaged in subject related conversations during team meetings.	Students solved individual tasks. Sometimes solutions of other teams were copied. Information was not shared, group discussion was not observed and tasks were completed on a superficial level. Students advised PBL was about improving writing skills. At times the teacher helped the team to problem solve.	All students in this team managed to satisfactorily pass both PBL subject 1 and 2.	Finishing culture
Team 2	5 Students (1 dropped out) – Sem 1 6 Students (3 new but, 1 dropped out) – Sem 2 Anglo-Saxon origin Local students Diverse school experience Same age group	Task focussed in semester 1, Socially focussed in Semester 2, Minimal collaboration in semester 1, no co-operation in Semester 2. Effective process was not identified, work load was shared unequally	1 leader throughout the year. Leadership was not effective as the leader completed most of the work individually.	1 student had an achieving motive and used achieving approaches. Other students were socially focussed and only approached learning at a surface level.	The leader engaged in pairing. Decisions involving the delegation of the tasks and sharing of information was taken by the leader of the team. Engaged in cheating the assessment system. Group learning was limited to the pair. Other students were mainly passive.	All the students passed the PBL subject 1 in semester 1. 3 students passed and 2 failed the PBL subject 2 in semester 2.	Finishing culture

Summary table of the characteristics of eight PBL teams (continued)

	Membership	Group processes	Team leadership	Learning approaches	Group learning and Outcomes	Productivity	Learning culture
Team 3	5 Students (1 dropped out) – Sem 1 Mixed ethnicity Local students Similar school experience Same age group	Effective group processes were not identified at the beginning. Students did not share mutual respect. Sexual prejudices led the team to split after semester 1	Most students did not display any leadership qualities. 1 student tried to persuade other students in the team to co-operate, but failed.	2 students had achieving motive and concentrated in finishing individual tasks thoroughly. 2 students had surface motive and were socially focussed. One of them was sure that he would fail anyway and refused to contribute.	Students of this group had social focus. They prepared to have more fun rather than learning. Solved tasks individually. Most students remained passive. Tasks were completed on a superficial level Design, methods or results were not discussed during team meetings.	1 student failed PBL subject 1 3 students passed PBL subject 1 The team was dissolved and students joined 3 different teams in Semester 2.	Finishing culture
Team 4	5 Students(1 dropped out) – Sem 1 5 Students (2 new) – Sem 2. Mixed ethnicity Local students Diverse school and work experience Different age groups (1 mature a student)	Students rarely socialised. Dominant member of the team organised the team work and delegated tasks to other students. He influenced the passive behaviour of most students as he did not trust them to complete the tasks.	Leadership was not effective. Mature age student dominated the team functioning and automatically assumed leadership.	1 student was career motivated and took an achieving approach. 3 students had a surface motive. They did not seek to perceive the new knowledge that they were exposed to by the leader. Group discussion or team work was not evident. These students used a surface approach.	The mature age student influenced the passive behaviour of other students. He thoroughly but individually problem solved and exceeded the expectation of the teacher. 1 student assisted the this student in laboratory work, another assisted in testing circuits that were already tested by the him.	All students passed Sem 1. Their grades ranged from credit to distinction. All students passed Sem 2. 1 student obtained a high distinction. Others obtained a credit or distinction	Performing culture

Summary table of the characteristics of eight PBL teams (continued)

	Membership	Group processes	Team leadership	Learning approaches	Group learning & outcomes	Productivity	Learning culture
Team 5	5 Students – Sem 1. 6 Students (3 new) – semester 2. One member dropped out. Mixed ethnicity Local students Diverse school and work experience Different age groups (2 mature age students)	All students showed willingness and formed a good bond. 1 mature age student was not inclusive and was not willing to share the workload. Some social discussions happened between the two mature age students. Others remained passive and worked when instructed. Members did not take responsible roles in Sem 2.	Leadership was effective but did not lead to successful group outcomes in semester 1. Leadership was contested in semester 2.	Both the mature age students were intrinsically motivated and used an achieving approach. This influenced the passivity of other students who gradually lost their motivation. These students were observed to have approached learning on a surface level	Students demonstrated organising and managing skills. Problem solving happened at a surface level. Team students did not attempt to understand the solution offered by the specialist member. Students of this group took shortcuts to solve the problem.	All students passed both the PBL subjects. 1 member received a high distinction in Sem1 but, only received a distinction in Sem 2. Other students obtained credits	Performing culture
Team 6	6 Students – Sem 1 Mixed ethnicity Local & International students Diverse school and work experience 1 mature age student. This team was not observed in Semester 2.	Most students were willing to participate. They met frequently, took responsibilities and worked on individual tasks. One students peer mentored and learnt from others tasks. Co-operated well as a team and were committed in learning new knowledge.	At the beginning of each problem the three team students rotated the leadership role. Leaders of the team offered support	3 students of the team were not intrinsically motivated and approached learning at a surface level. 1 student had achieving motive and used an achieving approach. 2 students were intrinsically motivated and used a deep learning approach.	Most students contributed completed each task individually and then shared their learning on a superficial level. One student did not contribute. Two members shared his tasks. Members used trial and error method to design and test. They problem solved thoroughly by improving their design	All students passed the PBL subject 1. Most members obtained either a credit or distinction. 1 member merely passed.	Performing Culture

Summary table of the characteristics of eight PBL teams (continued)

	Membership	Group processes	Team leadership	Individual learning approaches	Group learning & outcomes	Productivity	Learning culture
Team 7	5 Local students (Anglo-Saxon) in Semester 1 7 Local & International students (Mixed ethnicity) in Semester 2 till week 5. 2 students (Anglo-Saxon) after week 5. Similar school experience in Semester 1, same age group	Effective group processes in semester 1. Students shared and discussed ideas. Worked collaboratively to solve each problem. Group processes was ineffectual in semester 2 as some students showed no willingness or commitment to learning. Team was split into two in the middle of semester 2, which complicated the process.	Effective leadership in semester 1. Every student shared the leadership role. 1 member organised team work and lead the team till week 5. No leader after week 5.	Students were committed to learning and completed their tasks thoroughly. All members approached learning deeply in Semester 1. At the beginning of semester 2, four members had no motivation and did not contribute anything to the group's progress.	Members demonstrated outstanding time management and problem solving skills. They solved individual tasks by discussing and brainstorming ideas. They learnt to collaborate and helped each other with their tasks. Constructed circuits after arriving at a common understanding.	All students obtained a distinction in Semester 1. In semester 2 one student obtained a distinction and the other obtained a high distinction.	Collaborative learning culture in Semester 1 Performing culture in Semester 2
Team 8	5 students in Sem 1 6 students in Sem 2 Multicultural Local & International students Diverse school and work experience Different age groups (1 mature age student)	Students socialised, were inclusive of each member. They took responsible roles and displayed positive team working behaviour. Students collaborated with each other and shared every task. They often met unsupervised and face-to-face to problem solve as a group. Students criticised, provided feedback and supported each other.	1 leader throughout the year. Outstanding leadership, team building, management and supportive qualities observed.	1 student was deeply motivated. Others were motivated to achieve high grades. The deeply motivated student became the leader of the group and influenced other team members to approach deep learning.	Students demonstrated outstanding communication, interpersonal, problem solving and time management skills. They consistently worked hard and produced more than one solution to each problem.	Students obtained grades between credit and high distinction. One student only managed to pass merely.	Collaborative learning culture