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A Phenomenographic Study of Introductory Physics Students: Approaches to their Learning and Perceptions of their Learning Environment in a Physics Problem-Based Learning Environment

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A Phenomenographic Study of Introductory Physics Students: Approaches to their Learning and Perceptions of their Learning Environment in a Physics Problem-Based Learning Environment

By

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A thesis submitted to the Dublin Institute of Technology,
for the degree of Doctor of Philosophy (PhD)

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DECLARATION

I certify that this thesis which I now submit for examination for the award of doctor of philosophy, is entirely my own work and has not been taken from the work of others save and to the extent that such work has been cited and acknowledged within the text of my work.

This thesis was prepared according to the regulations for postgraduate study by research of the Dublin Institute of Technology and has not been submitted in whole or in part for an award in any other Institute or University.

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ABSTRACT

This phenomenographic study describes students' approaches to learning and their perceptions of the learning environment in an introductory physics course which is taught using a problem-based learning approach. This research builds on previous studies which showed that these students develop a greater conceptual knowledge than their counterparts in a more traditional learning environment. However, these studies also found there was a considerable variation in this development among the students. Many students excelled in the problem-based learning environment while others showed very little development even though they engaged fully with the pedagogy.

This study aimed to examine and describe the students' approaches to learning. The definitions of surface, strategic and deep approaches to learning are not appropriate in this context and could not be applied as all students engaged fully in the collaborative problem-solving process, albeit in different ways, and hence displayed none of the characteristics of the traditional surface approach and many, if not all, of those associated with the deep approach. Many previous research studies have shown that these 'traditional' approaches to learning can manifest in different ways and this is primarily due to the influence of the students' perceptions of the learning environment. Therefore, this study also aimed to determine the students' perceptions of the problem-based learning environment and examine their influence on the students' approaches to learning.

This study was conducted using phenomenographic methodology to collect, analyse and interpret data from twenty individual semi-structured interviews with introductory physics students. It presents a systematic way of identifying the variations in the students' approaches to their learning in a problem-based learning environment and the variations in students' perceptions of the learning environment. The study also involved the observation of the students' within the problem-based learning environment in order to examine the manifestation of their approach. Finally, a quantitative inventory was used as a pre- and post-test to ascertain the students' conceptual knowledge development. Relations between

the approaches, perceptions, actions and conceptual knowledge development were then examined.

The findings from this study reveal that students approach their learning in one of three ways: *PBL deep*; *PBL strategic*; and *PBL surface*. These approaches have similarities to the three traditional approaches mentioned above but have clear differences as well. In particular in terms of their link to the students' conception of understanding. A link was also established between students' perception of the learning environment and their approach to learning. The findings also indicated an alignment between approach, perception, actions taken in problem-based learning environment and the development of conceptual knowledge.

This research provides an insight into, and a better understanding of, the way introductory physics students approach their learning in a problem-based learning environment that is constructively aligned to develop understanding. It also underlines the significance that students' conceptions of understanding and perceptions of the learning environment will have on influencing their approach to learning. This study can inform problem-based learning course design, tutoring and teaching and assessment practices not only in physics education but in any discipline where conceptual understanding is a primary learning outcome.

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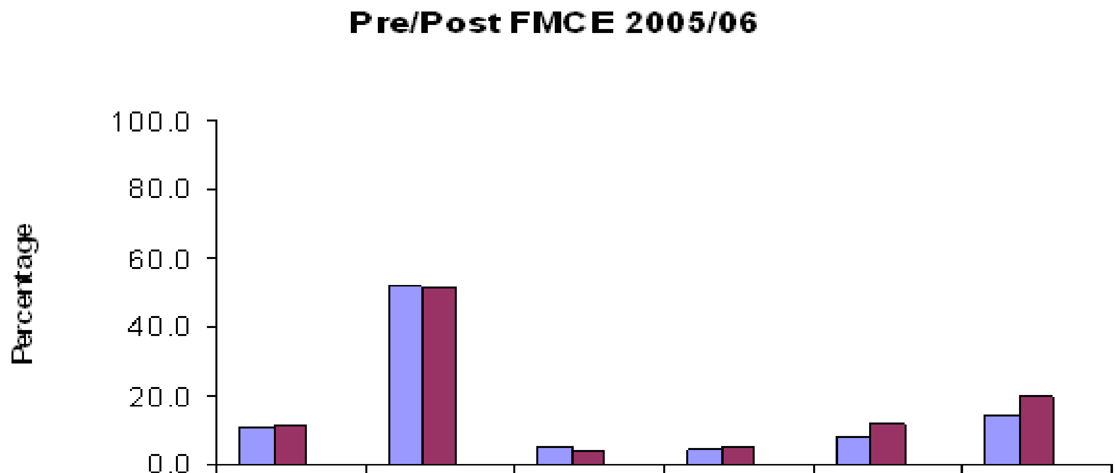
CHAPTER 1

INTRODUCTION AND CONTEXT

1.1 Introduction

This research study originally set out to examine why students in a problem-based learning environment achieve greater gains in conceptual understanding as measured by the Force and Motion Conceptual Evaluation (FMCE) than students taught in a traditional learning environment. From this initial inception, the study focused on two key aspects of the students in this learning environment that research has shown to have a strong influence on the quality of their learning experience: their approach to learning in and their perception of their learning environment.

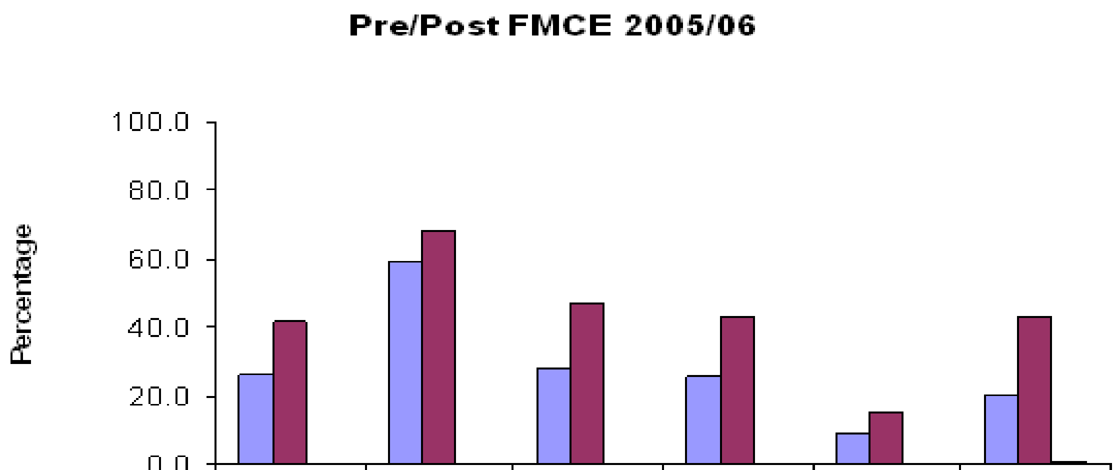
Previous research by Laura Walsh (Walsh 2008, Walsh *et al*. 2006, 2007, 2009) indicated that there was a significant difference in outcomes on the FMCE (explained in detail in section 3.4.3.1) for students learning physics through problem-based learning and students learning physics through traditional lectures and tutorials. Figure 1.1 displays the results of the FMCE for the cohort of students who in 2005/2006 were taught through traditional lectures and figure 1.2 displays the results of the same year for the cohort of students that were taught through problem-based learning. As can be seen, there is clearly a visible difference between the two sets of results with the problem-based learning cohort achieving much higher gains than the traditional students. Of course this may not necessarily be attributed to problem-based learning as another fundamental difference between the students was that the problem-based learning cohort would have chosen to major in physics. Whereas for the traditional cohort, physics would have been a supplemental subject to their main subject choice. However it was not until a different course (a lower level programme) changed its primary delivery method from traditional lectures in one year to problem-based learning in the subsequent year did it become justifiable to attribute a significant difference in gain to the problem-based learning environment as indicated by figures 1.3 and 1.4



	Overall	Velocity	Accel	Force (1,2)	Force (3)	Energy
Pre-%	10.9	51.7	5.6	4.4	8.1	14.6
Post-%	11.5	51.3	3.7	5.2	11.6	19.6
Gain 0-1	0.01	-0.01	-0.02	0.01	0.04	0.06

FMCE scores broken down into overall and sectional scores

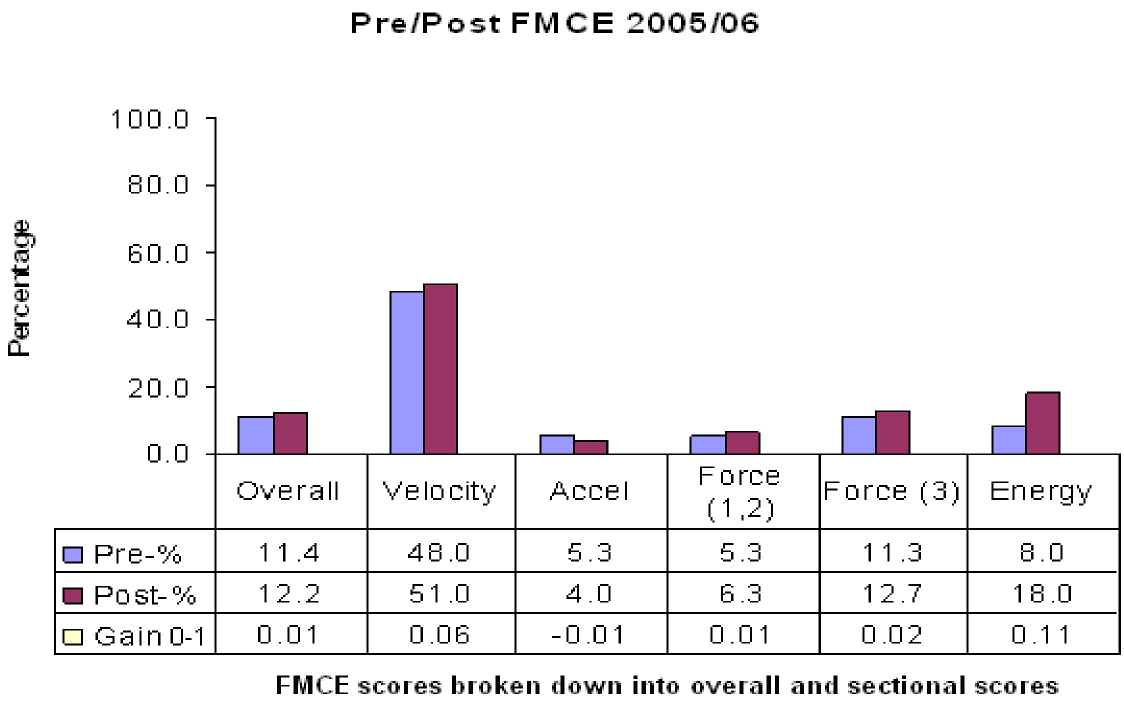
Figure 1.1 Students taught through traditional means for 2005/2006 (Source taken from Walsh (2008))



	Overall	Velocity	Accel	Force (1,2)	Force (3)	Energy
Pre-%	26.4	59.1	27.9	25.6	9.1	20.5
Post-%	41.6	68.2	47.0	43.2	15.2	43.2
Gain 0-1	0.21	0.22	0.26	0.24	0.07	0.29

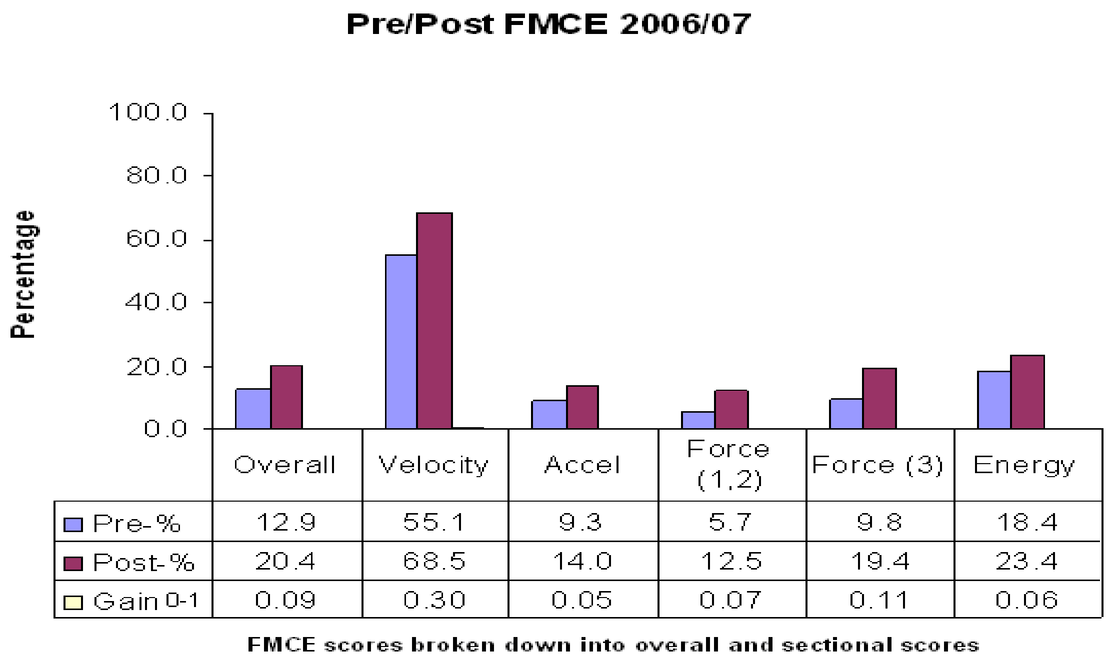
FMCE scores broken down into overall and sectional scores

Figure 1.2 Students taught through problem-based learning for 2005/2006 (Source taken from Walsh(2008)



	Overall	Velocity	Accel	Force (1,2)	Force (3)	Energy
Pre-%	11.4	48.0	5.3	5.3	11.3	8.0
Post-%	12.2	51.0	4.0	6.3	12.7	18.0
Gain 0-1	0.01	0.06	-0.01	0.01	0.02	0.11

Figure 1.3 Traditionally taught Level 7 course for 2005/2006 (Source taken from Walsh (2008))



	Overall	Velocity	Accel	Force (1,2)	Force (3)	Energy
Pre-%	12.9	55.1	9.3	5.7	9.8	18.4
Post-%	20.4	68.5	14.0	12.5	19.4	23.4
Gain 0-1	0.09	0.30	0.05	0.07	0.11	0.06

Figure 1.4 Same course except taught through PBL following switch in 2006/2007 (Source taken from Walsh (2008))

A conclusion taken from Walsh's research was that on average students in the problem-based learning environments gained a better understanding of the mechanics concepts. However there was a significant variation in individual problem-based students' gains in conceptual understanding. These two conclusions were the starting point for this study as it attempted to understand what it is about this learning environment or the way that students interact, perceive or approach the learning environment that results in this desired outcome of better understanding. But also the question must be asked as to why all the students do not demonstrate an increase (even in varying amounts) when they have engaged in this constructively aligned curricula. Even students who engage in the process and try hard do not necessarily develop any significant understanding.

According to Biggs 3P model (Biggs 1989) illustrated in figure 1.5 desirable learning outcomes are influenced by presage (student context and teaching context) and process (approaches to learning). Biggs in figure 1.5 is drawing attention to the relationship and interrelationships between approaches to learning and the variables in student context and teacher context that can influence a students learning outcomes.

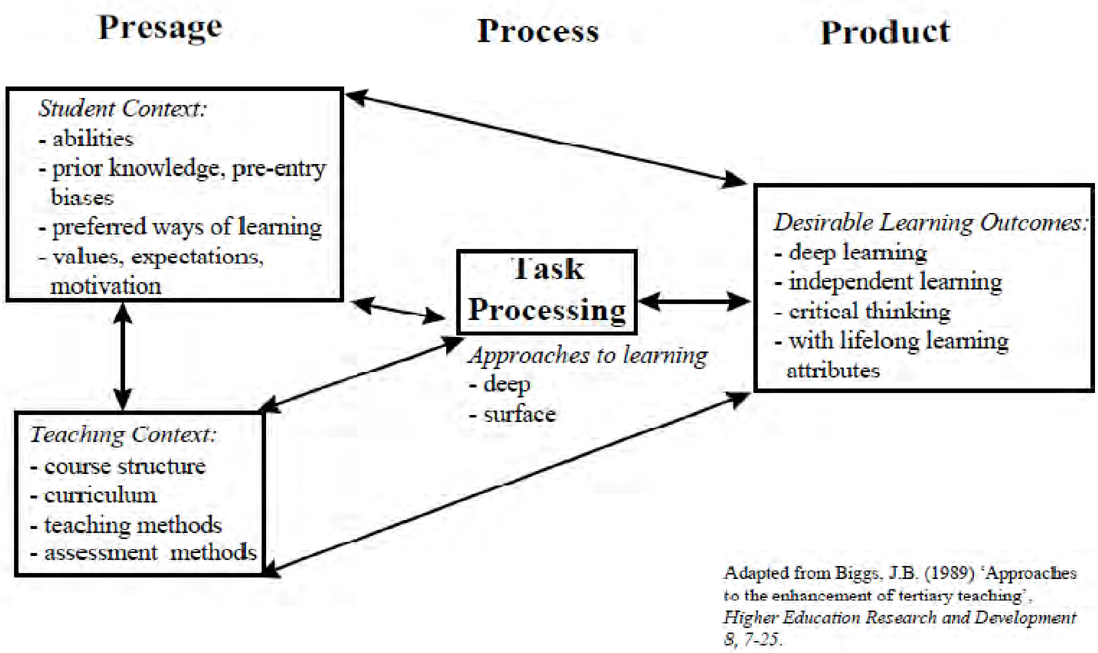


Figure 1.5 Biggs' 3-P Model of learning (Source taken from *Learning Matters at Lingnan, 1999, page 1*)

Previous research has shown that traditionally students approach their learning in one of three ways: deep, surface or strategic (Biggs 1979, Ramsden 1981 and Ramsden & Entwistle 1981), and these approaches to learning are greatly influenced by a student's perception of the learning environment (Entwistle 1987, Ramsden 1987, Thomas & Rohwer 1987). From Biggs 3-P Model above and previous research (Meyer *et al.* 1990) it is clear that there are relationships between approach, perception and desirable learning outcomes. In the past Trigwell & Prosser (1991) have encouraged researchers to examine such relationships:

> *"in future research, it is the set of relations between approaches, perceptions and outcomes which we believe is most important for practice and require substantially more research" (p. 263)*

According to the literature (Ramsden 1992), approaches to learning are context dependent and so the traditional definitions of surface, strategic and deep approaches to learning are not appropriate for a context where students are engaging in a collaborative problem solving process. The context of the research described here also differed in respect that the physics course was a constructively aligned problem-based learning course with learning outcomes that prioritise conceptual understanding. Entwistle (1997) points to the scarcity of research that examines approaches to learning in particular learning contexts:

> *"the idea of a deep approach needs to be reformulated to show how it emerges in a particular course of study, while students need to be shown how they can apply different learning processes (including memorisation) appropriately in seeking conceptual understanding. This is an area of research which is, so far, undeveloped, and needs attention" (p. 216)*

Given the influence that approaches to learning and perceptions of the learning environment have on the desirable learning outcomes, the primary aim of this study was to discover the qualitatively different ways in which the introductory physics students in the problem-based learning course approach their learning and the qualitatively different ways they perceive their learning environment and the relationship between approach and perception.

The results of this primary aim will have repercussions locally in the form of curriculum design and informing tutors, and globally in informing the ‘approaches to learning’ research community on the effects a constructively aligned problem-based learning environment has the students’ approaches to learning. In a proposal by the Strategic Initiatives Fund (SIF), the Universities within Ireland proposed a “radical overhaul of undergraduate teaching” and a major part of this radical overhaul is an emphasis to “make group learning the norm rather than the exception”. With such a shift towards these student orientated group learning approaches it is important to conduct research that will inform curriculum design and contribute to the growing body of knowledge related to group learning in order to improve teaching practice in such learning environments. This study will make such a contribution. The findings from this research study will increase our understanding of how students learn and develop conceptual understanding within the group learning environment. With this increased understanding, educators will be better equipped to facilitate group learning.

1.2 Context of research

In the context of Irish higher education, in science courses there has been a drop in the number and ability in student applicants which has meant that new entrants to physics courses have less prior physics knowledge than before and do not tend to be as motivated as students in previous years. As a result of these factors science educators in higher education began taking a more critical look at not only what is being taught but also how it is being taught (Institute of Physics 2001). Since 1999 the School of Physics in the Dublin Institute of Technology (DIT) has been critically analysing its pedagogical strategy, leading to a reconsideration of teaching and assessment practices. In July 1999, the School started investigating the feasibility of using more student-centred approaches in physics education and through consultation with other educators and members of the DIT’s newly formed Learning and Teaching Centre, possible approaches to physics education were devised. In 2001 the School of Physics set up the Physics Education Research Group (PERG) to carry out research to inform curriculum development, teaching and assessment practices. In the same year members of the group engaged in collaborative action research in order to design, implement and evaluate a first year physics problem-based learning course (Bowe *et al.* 2002). Problem-based learning is now the primary pedagogical method of delivery of introductory physics within the School of Physics. This will be discussed in further detail in section 1.3.2 below.

Crucial to the design and intention of the problem-based learning course implemented in the School of Physics is that it is constructively aligned to encourage students to adopt a deep approach to their learning. Constructive alignment, a term used frequently in this thesis, is defined by Biggs (2002) as:

> *An approach to curriculum design that optimises the conditions for quality learning. The 'constructive' aspect refers to what the learner does, which is to construct meaning through relevant learning activities. The 'alignment' aspect refers to what the teacher does, which is to set up a learning environment that supports the learning activities appropriate to achieving the desired learning outcomes. The key is that the components in the teaching system, especially the teaching methods used and the assessment tasks, are aligned to the learning activities assumed in the intended outcomes. The learner is 'trapped', and cannot escape without learning what is intended (p. 1)*

Therefore a course that is constructively aligned to reward a surface approach is one in which understanding of the concepts is not emphasised and reward is given to the reproduction of material to be learned. An evaluative research study (Bowe & Cowan 2004) has confirmed that the physics problem-based learning course was constructively aligned to require students to adopt a deep approach and reward them for doing so. Students taking the Leaving Certificate (see section 1.3.1) exam as an entrance exam into college are predominantly rewarded for taking a surface approach to their learning. As a result, students' prior experiences of assessment and their learning environment is one that encourages a surface approach. The new environment the physics students are entering is an active student-centred learning environment that prioritises conceptual understanding. Understanding of concepts or a concept is another frequently used term in this study and while there is no general definition in educational of what it means to understand a concept, Prosser (1980) gave the following definition which is appropriate for this study:

> *Understanding of a concept would involve more than recall. It would also involve comprehension, i.e. being able to use the concept when being asked to do so***,** *and application, i.e. being able to use the concept in situations where its use is not obvious. Failure to understand a concept not only depends upon a lack of knowledge, but also upon the range of reasoning patterns available to the student when attempting to solve problems involving the concept (p. 206)*

This is the first time many, if not all, of these students will be confronted with a student-centred approach focused on understanding and in the form of group learning which involves listening to varied interpretations of their peers where they have the responsibility of comparing, contrasting and criticising these interpretations for themselves. The students can no longer sit back and wait to be told the right answer, as they may have in the past. This means that the context of the study is not just students approaching their learning in the problem-based learning course but also students adjusting to the new environment. It is also worth noting that although the physics course is constructively aligned to require students to take a deep approach, the other elements of the programme, for example, biology would be aligned for students to adopt a surface approach.

From Biggs 3p model it is clear that teaching context also influences learning outcomes and Trigwell *et al.* (1994) have emphasised the impact teachers approaches to teaching have on students approaches to their learning and the quality of their learning outcomes. In the context of the DIT problem-based learning physics course, the course has been designed so that tutors adopt what Trigwell *et al.* (1994) describe as:

> *A student-focused strategy aimed at students changing their conceptions. This approach is one in which teachers adopt a student-focused strategy to help their students change their world views or conceptions of the phenomena they are studying (p.81)*

Approaches to learning research shares its origins with the phenomenographic research methodology and there have been many phenomenographic studies carried out to examine students approaches to learning (Marton & Saljo, 1976a, 1976b and Ellis *et al* 2007) and others that examine students' perceptions of their learning environments (Love & Fry 2006 and Domin 2007). The phenomenographic methodology will be discussed in more detail in

Chapter 4 and the results of previous approaches to learning research will be discussed in detail in Chapter 2. A phenomenographic study focuses on a relatively small number of subjects and identifies a limited number of qualitatively different and logically interrelated ways in which a phenomenon or a situation is experienced. To clarify, the term *experience* here does not specifically refer to knowledge of or involvement in approaching their learning in physics but instead refers to how the students are aware of their approach to learning physics. In this study the phenomenographic approach will be used as a systematic way of identifying the variations in the students' approaches to their learning in a problem-based learning environment and the variations in their perceptions of the learning environment.

Given the focus on a relatively small number of students (20) the latter parts of this study which involve correlations between qualitative results and the quantitative elements (FMCE results/assessments) are limited in respect to the firm conclusions that can be drawn. The intention behind these quantitative elements is to be merely illustrative and to give more insight into the relationship introductory students' approaches to their learning and perceptions of their learning environment have to their learning outcomes. Assessment can have multiple meanings depending on the context but in this learning environment assessment is based on quality not quantity. For example the end-of-year assessments assess students problem solving skills and conceptual understanding. The qualitative observation of students' actions should be viewed as illustrative also, as again the significance of the results are subject to the small number of research participants.

1.3 Research setting

1.3.1 Third level entry system

The National Qualifications Authority of Ireland (NQAI 2009), established in 2001, determines the policies and criteria for the National Framework of Qualifications (NFQ) in Ireland. The NQAI itself has three primary objectives that relate to the framework:

- The establishment and maintenance of a framework of qualifications for the development, recognition and award of qualifications based on standards of knowledge, skill or competence to be acquired by learners;
- The establishment and promotion of the maintenance and improvement of the standards of awards of the further and higher education and training sector, other than in the existing universities; and
- The promotion and facilitation of access

The NQAI determined that the framework would be based on levels, where each level has a specified indicator. The framework consists of 10 levels and the levels set out a range of standards of knowledge, skill and competence. In short, the levels relating to higher education awards in Ireland are as follows:

Level 10: Doctoral Degree
Level 9: Masters Degree and Post-graduate Diploma
Level 8: Honours Bachelor Degree and Higher Diploma
Level 7: Ordinary Bachelor Degree
Level 6: Advanced Certificate and Higher Certificate
Level 5: Level 5 Certificate
Level 4/5: Leaving Certificate

Almost all students who participated in this study enrolled in the Dublin Institute of Technology following completion of the Irish Leaving Certificate (further details of the participants will be provided in Chapter 9). The Irish third level entry system is based on a CAO (Central Applications Office) points system whereby a certain number of points are allocated to each grade achieved in the Leaving Certificate examinations. The maximum number of points is 600 and this is based on a Leaving Certificate result of six A1s at honours level. In secondary school students can choose to study each subject either at ordinary (lower) level or honours (higher) level; students usually study seven subjects but only the results from the best six are taken into account. An A1, representing a grade of 90% or better, in an honours subject merits 100 CAO points, whereas an A1 in an ordinary level subject merits 60 points. A complete table of CAO points and the corresponding grades can be seen in Appendix A. The students participating in this research had CAO points ranging from 160 to 530; however the study also included students who entered one of the courses through the secondary school exams system of another country, students who transferred from other courses and those who entered their programme of study on an interview basis (e.g. mature students – students over 23 who have returned to education after a period of two or more years). Therefore the students who participated in this study entered third level education with a range of abilities and almost 20% of them had not studied physics for the Leaving Certificate.

The students were in one of the following three 4-year honours degree programmes in a physics discipline:

- Physics Technology
- Physics with Medical Physics and Bioengineering
- Science with Nanotechnology

To clarify at this point, a "programme" refers to an entire degree programme which is offered by the Institute whereas a "course" refers to an element within the programme (for example the introductory physics course in the first year of study). "Modules" are units of learning and each module is assigned a set number of European Credit Transfer and Accumulation System (ECTS) credits. For example within the 4 year Physics Technology programme, the first year physics course consists of 2 modules, each 10 ECTS credits.

1.3.2 Honours degree physics programmes

The research participants are a cross section of three honours degree physics programmes which share the majority of their modules with the exception that in first year the students in the Physics Technology course do not complete a module in Biology. All the same lecturers, classes, examinations, assessments and laboratories in relation to the subject of Physics are taken by the research participants. After first year the courses still share modules but begin to diverge into their respective subject specific areas. Physics is taught through problem-based learning for students entering their first year of the level 8 physics degree programmes since its design and implementation in 2001 (Bowe & Cowan 2004; Bowe 2005, 2007). The students, who work in groups of four or five, have four hours of problem-based learning classes per week. During this time they must brainstorm to identify ‘ideas’, ‘facts’, ‘learning issues’ and ‘tasks’, for a problem based on a subject for which they have received no formal instruction. The students may use any resources that are available to them and are encouraged to complete the problem by the end of the second two-hour session. They are expected to work in groups both during and outside class time in order to solve the problem. They must then present the problem in a predefined manner before the next problem is undertaken. The role of the ever-present roaming tutor in the class is to facilitate learning by asking probing questions, guiding the students and continually assessing the students’ progress. In conjunction with the classes is a three-hour project-based laboratory and a one-hour tutorial. The tutorial takes the form of a recitation period during which students are given the opportunity to solve typical end of chapter algorithmic problems in the presence of a tutor or supervisor. An example of a problem-based learning problem given to these students during the mechanics section of the module is provided in Appendix B. The students are assessed formatively and summatively throughout the year and the end of semester exams are ‘open book’. For a more detailed description of the problem-based learning course and the research that has been carried out on this type of learning environment see section 3.3.

The other modules are taught through traditional lecture based methods which for comparison I will give a brief description of. The traditional lecture-based modules consist of three hours of lectures per week, which are delivered by a single lecturer. The lecturer typically delivers the course material in one of two ways: he/she may provide the students with photocopied notes containing the material and proceed by discussing and explaining the material during the lecture or he/she may use the whiteboard to deliver the material, in which case the students are expected to take their own notes. The students are not required to do ‘homework’, although individual lecturers may suggest reading material and/or problems to attempt between classes there is no incentive for the students to do so (e.g.

continuous assessment mark). It is during the one-hour tutorial each week that students have the opportunity to reflect on the material delivered in class. Also incorporated into the course is a two-hour laboratory session each week, which is also carried out in a traditional manner, that is, students are presented with a lab manual and are required to carry out the experiment as per the manual guidelines. The students' learning is assessed using closed book exams at the end of the modules.

1.4 Primary aims and objectives of the research

Although the research began by assessing students background information and attitudes to physics, I will discuss the aims and objectives in the order presented in this thesis which is also the order of significance. The research focused on qualitative evaluations of the students' experiences of approaching their learning in a problem-based learning environment constructively aligned to develop understanding and the perceptions of this learning environment. In order to achieve these overall research objectives a phenomenographic approach was used to answer the main research questions:

- What are the qualitatively different ways in which introductory physics students approach their learning in a problem-based learning environment constructively aligned to develop understanding?
- What are the qualitatively different ways in which introductory physics students perceive a problem-based learning environment that is constructively aligned to develop understanding?

A research question regarding conceptions of understanding, which were initially overlooked, emerged as an important theme from the analysis of the pilot interviews. So questions that would encourage students to discuss their conceptions of understanding was introduced to the interview and the following research question was formed:

- What are the qualitatively different ways in which introductory physics students conceive understanding?

After answering these questions, the research focused on relating approach to perception and so correlations were made between students approach to the learning environment and perception of the learning environment in order to answer the question:

- What is the relationship between students approach to learning and their perception of the learning environment?

1.5 Secondary research questions

From this point, as mentioned previously, the research began to focus on the individual students and individual relationships. Each student was placed into the approaches to learning category that most appropriately matched them as evidenced through comparison between transcripts and the themes of expanding awareness. The same was repeated for perceptions of the learning environment to answer the following questions for the students who took part in the study:

- How many students are in each approach to learning category?
- How many students are in each perception of the learning environment category?

Once the above questions were answered the attention of the study then focused on finding out how each approach/perception manifested in the students' actions within the problem-based learning environment. This was investigated by observing video tapes of the students working in problem-based learning sessions to answer the following question:

- How did students approach/perception manifest in students actions in problem-based learning?

Having the approach/perception and actions of the students I then examined students' results on end of semester exams, continuous assessment and employed the use of a research based diagnostic tool in a pre and post test capacity to answer the following questions:

- How does a student's approach/perception influence their gain in conceptual understanding of mechanics?
- How does a student's approach/perception influence their achievement of the learning outcomes?

Then in order to give more context to the study, information was gathered about students' educational background and approach to exams in the learning environment via interviews. A research based diagnostic tool was also used to assess students' attitudes to physics. Having gathered all this information the final question of the study to be asked was:

- What is the correlation, if any, between a student's approach to their learning, perception of the learning environment, conception of understanding, actions in learning environment, results in conceptual knowledge gain, results on learning outcome and background information?

In essence the final question is an attempt to give a detailed overview of how students approach the problem-based learning environment (approach) and what is the reasoning for taking such an approach (perception of learning environment/conception of understanding/background information). In turn how does their approach manifest itself in the problem-based learning environment and finally how does their approach affect their development of conceptual knowledge and their achievement of the learning outcomes of the course?

The implications that the answers to these research questions may have for physics education, physics educators, problem-based learning tutors and students are discussed in the final chapter (Chapter 11).

1.6 Outline of thesis

This chapter has provided the context in which this research is based and includes a description of the research setting, followed by the aims and research questions of the study. Chapter 2 begins the literature review with a brief overview of prevalent learning theories followed by a succinct summary of the relevant literature pertaining to approaches to learning research.

Chapter 3 continues the literature review with a discussion of the problem-based learning research which informed this research. The chapter also presents previous physics education research on students' conceptual understanding. It includes a brief examination of previous research on conceptions of learning and understanding. The literature from Chapter 2 and Chapter 3 is reflected on later in the thesis in light of the research findings.

Chapter 4 outlines the research design, which firmly places the research within the phenomenographic tradition and describes the theoretical and methodological assumptions associated with this research tradition. It also provides the reader with a description of the methods employed to obtain and analyse the data and finally introduces the research participants.

Chapter 5 is the first and most important of the findings chapters and contains the phenomenographic findings in the form of outcome spaces relating to students approaches to learning in the physics problem-based learning environment (see Chapter 3) which are described and discussed.

Chapter 6 is the second chapter that contains phenomenographic findings again in the form of outcome spaces relating to students perceptions of the problem-based learning environment which are described and discussed. This chapter also contains a discussion that relates the findings from Chapter 5 to the findings of Chapter 6.

Chapter 7 is a point of departure from the phenomenographic approach and contains an overview table of the actions that students took in the problem-based learning environment using an observation technique (Chapter 4 and Chapter 7). The results are described briefly and contains both a self contained discussion and a discussion that relates the findings to the findings of Chapters 5 and 6.

Chapter 8 is another point of departure as the quantitative data pertaining to the conceptual knowledge state of the participating students is presented. The quantitative data presented is in the form of normalised gain (see Chapter 4) results for students on a conceptual evaluation and their scores on end of year and continuous assessments. Again there is a self contained discussion of these results and then a discussion that relates the results back to the previous chapters.

Chapter 9 provides background information on the students in the form of their age and prior physics experience. It also displays students prior mechanics knowledge as assessed by the same conceptual evaluation as Chapter 8 and students attitudes to physics using a different evaluation. There is a brief self contained discussion and another that relates the findings to previous findings from previous chapters.

Chapter 10 is an accumulation of all the findings from the study and includes a discussion that relates all of the separate findings to each other and gives a detailed picture of each approach to learning.

Chapter 11 concludes the thesis by summing up the main findings and providing overall conclusions. This chapter also includes a discussion of the implications of the study for physics students and educators and makes recommendations for further work.

CHAPTER 2

LITERATURE REVIEW – LEARNING THEORIES AND APPROACHES TO LEARNING

2.1 Introduction

As outlined in Chapter 1, the central questions in this study are concerned with the variations in approaches by students to learning in the context of problem-based learning and the relationships, if any, between those approaches to learning, their perceptions of the learning environment, their actions within the problem-based learning groups and their achievement of the learning outcomes. This study draws on many of the findings of previous physics education research and general education research in the realms of problem-based learning, approaches to learning and group learning. The origin of much of the research reviewed in the following sections and the theories in Chapter 4 can be found in Marton and Saljo's two papers (Marton & Saljo 1976a, 1976b) which examined the variation in approaches to learning by students in a reading task. This study was not only the foundation of approaches to learning research but also the origins of the phenomenography methodology which this study employs.

In many ways this research project's main question is a replication of Marton and Saljo's original research into how students approach their learning, except this study is investigating approaches to learning in the context of a problem-based learning physics course during a time period where students are first introduced to it as a pedagogical approach. It also investigates how these approaches manifest themselves within the actions of the students participating in a problem-based learning course and the factors that influence this approach to learning. As will be discussed in section 2.3.9 there are many factors which have been attributed to influencing a student's approach to learning and a review of these factors and approaches to learning research can be found in sections 2.3.9 and 2.3.12. As the research progressed I endeavoured to review all of the pertinent and relevant literature. This chapter provides a succinct review of the relevant literature and includes a review of learning theories and approaches to learning research in sections 2.2 and 2.3.

2.2 Learning theories and approaches to learning research

2.2.1 Introduction

In the following section several learning theories are introduced and discussed as the majority of educational research has its foundation in one or more of these theories. For example, at the heart of the design of problem-based learning is the constructivist learning theory which would not have emerged without research and thought into cognitivism and behaviourism. The section starts with the first and simplest learning theory, behaviourism and moves chronologically onwards.

2.2.2 Behaviourist learning theory

Behaviourists see learning as a straightforward process of response to stimuli. Rewards or positive reinforcement are believed to strengthen the response and, therefore, result in changes in behaviour. The same is true for negative reinforcement with punishment resulting in changes in behaviour also. According to this theory the display of a change in behaviour means that learning has occurred. The central tenet behind the learning theory is that behaviourists limit themselves “to things that can be observed, and formulate laws concerning only those things” and what can be observed is “what the organism does or says” Watson (1997, p. 6). One of the keys to effective teaching using the behaviourist approach is discovering the best consequence (stimulus) to shape behaviour. There have been many philosophers, and later psychologists, through the ages to whom the promotion of this theory has been attributed but in more recent times the names most associated with the learning theory are Pavlov, Watson, Thorndike and Skinner.

Pavlov (Watson 1997) illustrated that neutral stimuli could be used to elicit a response from animals. His experiments involved the conditioning of dogs. Initially with no conditioning, ringing the bell caused no response from the dog. Placing food in front of the dog initiated salivation. During conditioning, the bell was rung a few seconds before the dog was presented with food. After conditioning, the ringing of the bell alone produced salivation (Dembo 1994). Watson and Skinner took these principles and demonstrated them on humans (Cheetham & Chivers 2001). They demonstrated that responses related to more complex behaviour could be achieved, which they termed "operant responses." One of the assumptions made by many behaviourists is that free will is illusory, and that all behaviour is determined by a combination of forces. These forces comprise genetic factors as well as the environment either through association or reinforcement.

The theory has been openly criticised for its simplicity and because behavioural theories do not account for free will and internal influences such as moods, thoughts and feelings. Behaviourism also does not account for other types of learning, since it disregards the operations of the mind, especially learning that occurs without the use of reinforcements or punishments. The theory also ignores the fact that people and animals have the ability to adapt their behaviour when new information is introduced to a problem or situation, even if a previous behaviour pattern has been established through reinforcement.

It does, however, influence educators even those involved in problem-based learning which is based on constructivist learning theory but contains the positive and negative reinforcement of feedback. Behaviourist theory maintains a focus on the change in observable behaviours as the manifestations of learning. The theory emphasises changes in behaviours due to the influence and control of the external environment, rather than the internal thought processes of the subject (Merriam & Caffarella 1999). Simply put, people will learn desired behaviours as a result of stimuli from their external environment that recognise and reinforce their behaviour in a positive manner. Undesired behaviours can be controlled or eliminated by an absence of attention to or recognition of such (Pritchard 2008).

Behaviourism comprises of several individual theories with three common themes:

- The emphasis is that observable behaviour rather than internal thought processes create learning;
- Ultimately it is the environment that creates learning and it determines what is learned, not the individual learner;
- Lastly it is the ability to understand the overall process, and the ability to repeat or reinforce that process that is a common to all theories.

The hypothesis behind the behaviourist learning theories is that all learning occurs when behaviour is influenced and changed by external influences. Grippin & Peters (1984, p. 56) emphasise that "contiguity…and reinforcement are central to explaining the learning process" and would be construed as the external influences. Contiguity is understood as the timing of events that are necessary to bring about behavioural change, while reinforcement refers to the probability that repeated positive or negative events will produce an anticipated change in behaviour (Watson 1997). This learning theory has its supporters and possible applications such as company standard operating procedures (SOPs), fire training, soldier training, apprenticeships etc. It can also be observed in the problem-based learning environment in the form of reaction to tutor feedback or reaction to scores on tests. A good example of behaviourist learning theory at work would be the use of recipe laboratories that require students to follow step by step procedures and which precludes any deep thinking. The simplistic external influence premise of behaviourist theory does not account for internal influences on learning such as the approach to learning which is the focus of this research study. Given the limited applicability of the behaviourist learning theory to this research study it is important to be aware of the theory but to focus more on learning theories that are focused on the internal workings of the mind.

2.2.3 Cognitivist learning theory

Cognitivist learning theory (or theories) was the natural progression from behaviourism as it became unable to answer questions about certain educational behaviours and social behaviours. For example, children do not imitate all behaviour that have been reinforced. Furthermore, days or weeks after their first initial observation, they may model new behaviour on the observed behaviour without that behaviour having been reinforced. The cognitivist theories take the perspective that students actively process information and learning takes place through the efforts of the student as they organise, store and then find relationships between information, linking new to old knowledge, schema and scripts (Baron & Byrne 1987). Cognitive approaches emphasise how information is processed. Two key assumptions underlie this cognitive approach: (1) that the memory system is an active organised processor of information and (2) that prior knowledge plays an important role in learning. Cognitive theories look beyond behaviour to explain brain-based learning. Cognitivists consider how human memory works to promote learning.

The following section gives a brief overview of several cognitive theories and then presents the general assumptions for contemporary cognitivism. The behaviourist Edward Tolmann (Robert & Dawson 1998) proposed a theory based on observations he made about rats in a maze that he found behaviourism could not answer. Some of the central ideas of his theory involved believing that behaviour should be studied at a local level. That learning can both occur without reinforcement and without a change in behaviour. Variables that intervene in the process of learning must be considered to have an effect and that behaviour is carried out with purpose and not just a reaction to an external influence. Finally, based on his research of rats, he posited that learning results in an organised body of knowledge; Tolman (Robert & Dawson 1998) proposed that rats and other organisms develop cognitive maps of their environments (Pearce 1997).

The next phase of cognitive theory came from a revolution in psychology which became known as Gestalt psychology. This occurred around the same time as Tolman's work and emphasised the importance of organisational processes of perception, learning, and problem solving. According to this theory, individuals were predisposed to organise information in particular ways. The main idea behind Gestalt theory is expressed by (Wertheimer 1944, p. 4) as follows "There are wholes, the behaviour of which is not determined by that of their individual elements, but where the part-processes are themselves determined by the intrinsic nature of the whole." Purveyors of the Gestalt theory believe that human experience cannot be explained unless the overall experience is examined instead of individual parts of experience (Ormrod 1999). The belief being that the learner structures and organises his/her experiences even though structure might not be, necessarily, inherent in the experience. The learner becomes predisposed to organise experience in particular ways based on their prior experiences and how they have structured them previously. So the learner will give a structure and organisation to an experience hence breaking down the experience into different structures that are organised in a specific way and need to be looked at as a whole to be understood. Adherents of the Gestalt theory viewed problem-solving as involving both restructuring and insight. It was proposed that problem-solving involves mentally combining and re-combining the various elements of a problem until a structure that solves the problem is achieved. According to Gestalt theory, stimuli only have meaning as they are cognitively organised by the person. Learning is based on changes in the perceptual process so true learning, or insight, occurs when the individual perceives new relationships within the structure (Bell-Gredler 1986).

The next step in the evolution of modern cognitivist theory is Piaget's developmental theory which included the idea of people being active processors of information. Instead of people being passive respondents to the environmental conditions that surround them, human beings are actively involved in interpreting the world and learning from the events around them (Mayer 1981). It also posited that knowledge can be described in terms of structures that change over time with development. Piaget also proposed the concept of schema.

As children develop, new schemes emerge and are sometimes integrated with each other into cognitive structures (Woolf 2008). Cognitive development results from the interactions that children have with their physical and social environments. The process through which people interact with the environment remains constant. According to Piaget, people interact with their environment through unchanging processes known as assimilation and accommodation. Accommodation occurs when one's internal structures adjust to the diversity of the environmental conditions around one, an individual either modifies an existing scheme or forms a new one to account for the new event. In assimilation, an individual interacts with an object or event in a way that is consistent with an existing scheme. People are intrinsically motivated to try to make sense of the world around them. According to this view, people are sometimes in the state of equilibrium and, they can comfortably explain new events in terms of their existing schemes. However when they can encounter events they cannot explain or make sense of, this is called disequilibrium: a mental discomfort. Through reorganising thought, people are able to then understand the previously non-understandable and return to equilibrium. In Piagets theory cognitive development occurs in distinct stages, with thought processes at each stage being qualitatively different from those at other stages (d'Ydewalle & Lens 1981). Eventually Piaget's theory became distinct from cognitive learning theories but it did contribute greatly to cognitive mental models.

One of the most important developments in cognitivism was the advent of the computer. The computer functions of storage, retrieval, manipulation, and problem solving were deemed to be analogous to the inner workings of the human mind (Barsalou 1992). Broadbent (Broadbent 1958) was one of the first to regard human memory as a type of processor. His proposal of sensory buffers and thoughts on short-term memory each played substantial roles in cognitivist theory (Bell-Gredler 1986). Another proponent of this model was Neisser (Neisser 1967) who discussed in detail the storage and retrieval of information from the human mind. According to his argument, information is stored in long-term memory as summary codes that are used to construct relationships during recall (Bransford 1979).

Although there is a discernable variation in cognitivist learning theories, the assumptions that underlie these theories display certain similarities. Cognitivists believe that:

- some learning processes may be unique to human beings;
- mental events are central to human learning and they must, therefore, be incorporated into theories of learning;
- systematic observations of peoples' behaviour should be the focus of scientific inquiry; however, inferences about unobservable mental process can often be drawn from such study;

- individuals are actively involved in the learning process. They are not passive receivers of environmental conditions; they are active participants in that learning process. In fact, they can control their own learning;
- learning involves the formation of mental associations that are not, necessarily, reflected in overt behaviour changes. This is contrary to the behaviourist position, where no learning can happen without an external behaviour change;
- knowledge is organised. An individual's knowledge is self organised through various mental associations and structures;
- learning is a process of relating new information to previously learned information;
- learning is most likely to occur when an individual can associate new learning with previous knowledge.

2.2.4 Constructivist learning theory

Constructivism is a theory of both knowing and learning and this succinct review aims to explore both of these areas with slightly more emphasis on the learning side of the theory. The way in which knowledge is conceived and acquired, the types of knowledge, skills and activities emphasised, the role of the learner and the teacher, how goals are established: all of these factors are articulated differently in the constructivist perspective. Within constructivism, like cognitivism, there are different theories based on different constructivist perspectives.

From the individual constructivist perspective, knowledge is constructed internally, and tested through interaction with the outside world (Biggs 1993). Individual constructivism developed as a reaction to the behaviourist and information-processing theories of learning and it conceptualises learning as the result of constructing meaning based on an individual’s experience and prior knowledge (Lowenthal & Muth 2008). From a Vygotskian social constructivist prospective, knowledge is thought to develop internally but in a process driven by social interaction with the outside world (Cobb 1996), hence social constructivists believe that learning occurs via the construction of meaning in social interaction, within cultures, and through language (Lowenthal & Muth 2008). From this perspective, the context, and particularly the social context, is of prime importance. It is the context which brings about knowledge development within individual students (Marton & Booth 1997).

Another type of constructivism that is popular among educationalists is radical constructivism. From a radical constructivist perspective, knowledge consists of mental constructs which have satisfied the constraints of objective reality. The learner constructs knowledge from his experiences in an effort to impose order on and hence make sense of those experiences (Hardy & Taylor 1997). Radical constructivism starts from the assumption that knowledge, no matter how it is defined, is in the heads of persons, and that the thinking subject has no alternative but to construct what he or she knows on the basis of his or her experience (Von Glasersfeld 1995).

While the radical and social perspectives of constructivism each emphasise particular distinctive points of theory, Ernest (1995, p. 485) argues that there is a set of theoretical underpinnings common to both:

- knowledge as a whole is problematised, not just the learner's subjective knowledge, but including mathematical knowledge;
- methodological approaches are required to be much more judicious and spontaneous because there is no road to truth or near truth;
- the focus of concern is not just the learner's cognitions, but the learner's cognitions, beliefs, and conceptions of knowledge;
- the focus of concern with the teacher and in teacher education is not just with the teacher's knowledge of subject matter and diagnostic skills, but with the teacher's belief, conceptions, and personal theories about subject matter, teaching, and learning;

- although we can tentatively come to know the knowledge of others by interpreting their language and actions through our own conceptual constructs, the others have realities that are independent of ours. Indeed, it is the realities of others along with our own realities that we strive to understand, but we can never take any of these realities as fixed;
- an awareness of the social construction of knowledge suggests a pedagogical emphasis on discussion, collaboration, negotiation, and shared meanings.

With regards to learning and the constructivist conception of learning, Von Glasersfeld (1995, p. 14) argues that: “From the constructivist perspective, learning is not a stimulus-response phenomenon; it requires self-regulation and the building of conceptual structures through reflection and abstraction”. In this paradigm, learning emphasises the process and not the product. How one arrives at a particular answer, and not the retrieval of an 'objectively true solution', is what is important. Learning is a process of constructing meaningful representations, of making sense of one's experiential world. In this process, students' errors are seen in a positive light and as a means of gaining insight into how they are organising their experiential world. The notion of doing something 'right' or 'correctly' is to do something that fits with "an order one has established oneself" (Von Glasersfeld, 1987, p. 15).

In this paragraph the learning process as it occurs in constructivism is illustrated descriptively. When a physical or mental action fails to produce a desired or expected result, a perturbation arises and the accommodation cycle begins (Von Glaserfeld 1989b). The experience is distinguished from its unperturbed counterparts, and the learner strives to resolve the perturbation. During this quest, the learner re-presents and compares experiences in an effort to determine what was unique about the perturbing experience and why her or his initial model of experience failed to account for it. Further, the learner often examines consciously his/her experiential model, by engaging in reflected abstraction in order to understand why his/her initial action produced an unexpected or undesired result. Regardless, while developing a viable solution the learner uses reflected abstraction to reorganise his or her model of experience and the activity that is guided by that model.

Once a viable solution is constructed the perturbation is neutralised and cognitive equilibrium is re-established. Constructivist theory, therefore, suggests that in order to learn individuals must rationalise novel perceptions in light of their current knowledge.

2.2.5 Non-dualistic learning theory

The former learning theories focus on the concept of learning as a process of relating new information to previously learned information or learning as a displayed change in behaviour. The non-dualistic learning theory is a departure from this focus and instead is a learning theory based on the experience of learning. Marton & Booth (1997) critique the learning theories which have been previously presented in the sections 2.2.1 to 2.2.4 in their book entitled “Learning and Awareness”. In the book they argue that Skinner’s behaviourist approach to learning was not sensitive to the distinction between the reinforcement (either positive or negative) potential of learning experiences and the content structure of experience. In as much as behaviourism could account for whether or not people do particular things, it could not account for or help to understand how they do what they do. In other words behaviourists are not interested in understanding how we gain knowledge about the world. Marton and Booth also critique Von Glasersfeld’s assertions (Von Glaserfeld 1990) that constructivism does not reject the concept of an independent reality and an individual world and the fact that the constructing of knowledge is the interaction of the individual world with the independent reality through the testing of constraints. However, Marton and Booth argue that if this is true, are those constraints which are tested by the independent reality, also not constructions. In that case, the constructions that we ourselves construct are the very things that are constraining our ability to develop knowledge.

Cognitive theory is also critiqued under several headings the first of which is that in the doctrine of cognitive theory all psychological explanation must be framed in terms of internal mental representation and processes by which representations are manipulated and transformed (Costall & Still 1987). Marton and Booth argue that the internal mental representation does not just lie around in your head but instead has to be used by something which is other than the representation itself. This brings about a paradox, that if a person was acting in the world then they would have a representation of the world made by the internal representation. But then the inner world would have a representation of this representation of the world. Then it follows that there must be something handling the representation of the representation and so on. Another critique of the idea of representations that is argued by Marton and Booth is that in this model of learning we receive sensory data from our sensory organs. The data is meaningless but is synthesised into an inner representation of the outer world. They question how a person may develop something meaningful out of something that has no meaning. The final critique of cognitive theory comes in the form of problem solving. If a person encounters a problem situation, according to cognitive theory, they must already have acquired a schema, a paradigm or a template for the class of problems for which the one they encounter belongs. By using the appropriate schema the problem can be solved, but how does one choose the appropriate schema. By identifying the schema needed to solve the problem you have already grasped the problem. But according to cognitive theory, the very grasping is supposed to be done by using the schema: another paradox.

Along with all of the criticisms of previous learning theories, Marton and Booth also put forward their theory of learning. Their learning theory takes into account the experiences of people and explores the physical, social and cultural world that people experience. They view the world as an experienced world by learners, neither individual constructions nor individual realities. The learners experience aspects of the world but are neither bearers of mental structures nor behaviourist actors, as Marton & Booth (1997) put it:

> *"The dividing line between "the outer" and "the inner" disappears. There are not two things, and one is not held to explain the other. There is not a real world "out there" and subjective world "in here". The world is not constructed by the learner, nor is it imposed upon them; it is constituted as an internal relation between them. There is only one world, but it is a world that we experience, a world in which we live, a world that is ours" (p. 13)*

Therefore, their learning theory is based on non-dualistic assumptions that knowledge represents ways of seeing, experiencing, thinking about the world and it is constituted through the internal relationship between the knower (subject) and the known (object) and not a fixed entity that is separate from other pieces of information including the learner. This line of thought is associated with "variation theory" and it follows that learning is the discernment of variation of critical aspects of an experience. This discussion is picked up again in Chapter 4 which relates this variation theory and the non-dualistic assumptions to the research method - phenomenography with a detailed discussion on the theoretical assumptions and perspectives that informed this approach to this study.

2.3 Approaches to learning

2.3.1 Introduction to approaches to learning research

This section provides a review of the literature pertaining to the area of educational research known as 'approaches to learning research', 'approaches to study research' or 'study orientations research'. It details the origins of approaches to learning research starting with the pioneering work carried out by Marton & Saljo (1976a, 1976b) and carrying on to more recent work that is particularly relevant to this research project (Ellis *et al.* 2007). The section focuses specifically on reviewing the progression of approaches to learning research and examining the previous approaches to learning that have been discovered in previous contexts and then, in turn, the factors that determine these approaches to learning.

2.3.2 Approaches to learning

Any discussion of approaches to learning must begin with the seminal work of Marton & Saljo (1976a, 1976b) in which the concept of 'approach to learning' was first coined and the original descriptions of approaches to learning as 'surface' and 'deep' were proposed. Marton and Saljo used a phenomenographic approach, which is explained in more detail later in Chapter 4, to discover the qualitatively different ways in which students approached a reading task. Students were asked questions about the meaning of certain passages and how they set about reading the passages. Their answers were then analysed, resulting in an outcome space (see section 4.4.1) describing the qualitatively different ways of approaching the reading task. From this outcome space Marton and Saljo concluded that they had found two clearly distinguishable different levels of processing or approaches, that of the deep and surface approaches. Initially Marton and Saljo did not use the term approaches to learning, instead calling their outcomes “levels of processing” but this was subsequently changed to be implicit in that an ‘approach’ not only included process but also the intention behind the process. It is this inclusion of intention that differentiates approaches to learning from merely describing a student’s behaviour.

The research of Marton and Saljo and their descriptions of approaches were subsequently verified by various interview and survey investigations carried out Biggs (1979), Laurillard (1979), Ramsden & Entwistle (1981) and Watkins (1983a, 1983b). As a result of this research a debate began on whether the approaches to learning are variable or fixed attributes of a student. Marton & Saljo (1976a) have argued from the beginning that the approaches they discovered are context dependent and, therefore, variable. Entwistle & Ramsden (1983) state that the ‘study orientations’ (approaches) they discovered were typically consistent ways in which a student approaches his/her studies in general.

However, Ramsden indicated that stability of orientation does not imply that the orientation is fixed and that the orientations depend on context, assessment and the curriculum of the course in question (Ramsden 1988). Biggs (1987a) also expressed a similar viewpoint that students may change their approach according to each different situation but that the extent to which change occurs is down to a student’s predisposition to change and capability for meta-learning (is discussed in more detail in section 2.3.11) and this is, in turn, influenced by their personal attributes such as prior knowledge or ability. Entwistle *et al*. (1979), Entwistle & Ramsden (1983) and Ramsden (1997) have all found that in different learning contexts students have taken different approaches to learning about the same phenomenon. It is also generally accepted in the research that approaches to learning are contextually dependent and are a relationship between the student and the context of the learning environment. Booth (1997), McCune & Entwistle (2000) argue that the essence of deep and surface approaches remains the same, but specific, important details may change from context to context.

After these initial studies had been completed and credence was given to the findings of Marton and Saljo, research began to increase within the area of approaches to learning in several different directions. Among the research that will be discussed below is a review of alternative approaches to learning other than the initial surface and deep. I also examine the factors that determine a students' approach to learning, the effects that a student's approach to learning has on his/her learning outcomes and research into how to influence a student's approach to learning.

In the first instance, I examine the deep and surface approaches to learning in detail. Throughout my review of the literature pertaining to approaches to learning, I have come across several different descriptions of the deep and surface approaches to learning and although they stay within the same broad representation, the following two sections begin with a presentation of the original descriptions as phrased by Marton & Saljo in their 1976 papers.

2.3.3 Approaches to learning – Deep

> *"In the case of deep-level processing, on the other hand, the student is directed towards the intentional content of the learning material (what is signified), i.e., they are directed towards comprehending what the author wants to say about, for instance, a certain scientific problem or principle." Marton & Saljo (1979 p. 3)*

According to Leung & Kember (2003) the following points describe a student who adopts a deep approach to learning:

- is interested in the academic task and derives enjoyment from carrying it out;
- searches for the meaning inherent in the task (if a prose passage, the intention of the author);

- personalises the task, making it meaningful to own experience and to the real world;
- integrates aspects or parts of task into a whole (for instance, relates evidence to a conclusion), sees relationships between this whole and previous knowledge;
- tries to theorise about the task, forms hypotheses**.**

Kember *et al.* (1999) described the motive behind a deep approach to be intrinsic: study to actualise interest and competence in particular academic subjects. Students who are taking a deep approach are characterised by the intention to understand and to extract meaning from the content to be learned and they have a preference for a learning environment which is likely to promote understanding. They have a tendency to relate ideas to previous knowledge, look for patterns, check evidence and critically examine arguments (Baeten *et al.* 2008).

There is a lack of research in the area of the manifestation of an approach through a student's actions in research literature. This is easily explained. Unless you are investigating in an active learning environment, observation of a student's actions in a lecture or tutorial would not be very insightful. However Chin & Brown (2000) while investigating students' approaches to learning in a chemistry laboratory did describe the following strategies for students adopting a deep approach:

- Visualising and generating mental images;
- Creating analogies to explain scientific phenomena;
- Hypothesising, constructing thought experiments, and predicting possible outcomes;
- Giving explanations and constructing theories;
- Invoking personal experiences and prior knowledge, and applying them to new situations;
- Asking questions.

Chin and Brown (2000, p. 110) also conclude that students adopting a deep approach "displayed a high level of reflective awareness, constantly monitoring and self-evaluating the status of their comprehension."

2.3.4 Approaches to learning - Surface

> *"In the case of surface level processing the student directs his attention towards learning the text itself, i.e., he has a 'reproductive' conception of learning which means that he is more or less forced to keep a rote learning strategy". Marton and Saljo (1979, p. 3)*

Leung & Kember in their 2003 paper also describe a student who adopts a surface approach to learning:

- Sees the task as a demand to be met, a necessary imposition if some other goal is to be reached (a qualification for instance);
- Sees the aspects or parts of the task as discrete and unrelated either to each other or to other tasks;
- Is worried about the time the task is taking;
- Avoids personal or other meanings the task may have;
- Relies on rote-learning, attempting to reproduce the surface aspects of the task (the words used, for example, or a diagram or mnemonic).

Students who are adopting a surface approach are characterised by having the intention to cope with the course requirements. According to Kember *et al.* (1999) students main purpose is to meet requirements minimally: a balance between working too hard and failing. They consider the course to be unrelated bits of knowledge or focus upon one part of the whole phenomenon (Entwistle 1997, Marton & Saljo 1997). Their emphasis is on memorising and reproducing factual content (Birenbaum & Rosenau 2006, Entwistle & Ramsden 1983) although Marton *et al.* (1996) have suggested that memorising can also be effectively used as part of a deep approach. This is discussed in section 2.3.7. A surface approach can be a predictor for poor performance (Baeten *et al.* 2008) unless the curriculum is constructively aligned to reward that approach. Students who adopt a surface approach have a preference for a learning environment which is perceived as facilitating rote learning.

2.3.5 Deep and surface: a comparison:

Chin (2003) made a detailed comparison between the deep and surface approaches to learning over five separate criteria of (1) generative thinking, (2) nature of explanations, (3) asking questions, (4) meta-cognitive ability and (5) approach to tasks. The following tables (Tables 2.1-2.5) taken from the Chin (2003) paper present the differences between the two approaches.

Table 2.1 Generative thinking – source taken from Chin (2003, p. 99)

Deep approach	Surface approach
Student tries hard and is motivated to venture ideas.	Student remains stuck, saying ‘I don’t know’, gives a response that does not directly answer the question and/or is brief.
Responses are longer, more sustained, and dwell more on a single idea.	Responses are shorter.
Responses are elaborate, incorporating examples, self generated analogies, daily life experiences, and past episodes.	Responses are less detailed and elaborate.
Thinking is maintained as a ‘chain reaction’ or ‘network of ideas’ where subsequent ideas are connected to the previous one(s).	‘Piecemeal thinking in spurts’. Student moves from one idea to another, groping around without a sense of directional link between the isolated ideas.
Language is more precise with specific referents.	Language is usually vaguer if the student is unable to think of specific referents.

Table 2.2 Nature of explanations – source taken from Chin (2003, p. 99)

Deep approach	Surface approach
Microscopic, more sophisticated, targeted, refers to a mechanism describing non-observable entities and a cause-effect relationship, or to personal experiences. Theory like.	Reformulation of question, ‘black box’ variety with no mechanism(observation, rote, global, cyclic), or macroscopic. Sometimes vague with non specific referent.
More detailed and elaborate, incorporating examples, analogies, real life experiences	Not elaborate
More forthcoming. Self-explanations (i.e. spontaneously generated requiring little or no prompting).	Usually given only when solicited. Requires more probing to produce more complete explanation.

Table 2.3 Asking questions – souce taken from Chin (2003, p. 99)

Deep approach	Surface approach
Wonderment questions: focus on explanations and causes (facts), predictions, resolving discrepancies in knowledge, application, or planning. Reflect curiosity, puzzlement, scepticism, or speculation.	Basic information questions: focus on factual recall of information or procedures.

Table 2.4 Metacognitive activity – source taken from Chin (2003, p. 100)

Deep approach	Surface approach
Student displays more cognitive self appraisal and regulatory control of learning process through ongoing reflective thinking	Student displays less self monitoring and self evaluation

Table 2.5 Approach to tasks – source taken from Chin (2003, p. 100)

Deep approach	Surface approach
Student is more persistent with a single idea	Student oscillates between ideas
Student attempts to generate ideas on his/her own	Student is more dependent on external sources for ideas
'Hands on-minds on' learning. Students engage in on-line theorising, spontaneously generates explanations or theories for cause-effect relationships to account for phenomena and anticipates outcomes	Less 'minds on' learning.
Student does not ignore puzzlement but ruminates over it	Student may ignore puzzlement
Student shows more sophisticated level of observation, extending to inferred patterns and trends. Discriminates more finely between differences. Thinks ahead, anticipating outcomes.	Students notices mostly gross, macroscopic features of the phenomenon.
Student attends to multiple foci.	Student has a single or more limited focus
Talk/comments pitched at conceptual, analytical, and metaconceptual, beyond observational and procedural levels.	Talk/comments pitched mainly at the observational and procedural level

Again although the above tables (2.1-2.5) are not necessarily describing the actions of either a deep or surface approach to learning, in an active environment they do provide a basis for comparison to some aspects of behaviour of a student adopting a deep or surface approach for such an environment. For example table 2.1 displays the contrast in behaviour between a deep and surface approach when generating ideas for the laboratory exercise in a group of two. While table 2.3 details the contrast in the type of questions a student adopting a deep and surface approach generates in such exercises. Overall the above tables outline the contrast in behaviours to multiple aspects of a laboratory learning environment.

2.3.6 Alternative approaches to learning

Investigations into the presence of alternative approaches to learning other than that of deep or surface began after the verification of Marton & Saljo's findings with Biggs (1979), Ramsden (1981) and Ramsden & Entwistle (1981) all identifying an alternative approach to learning which they labelled "strategic" or "achieving". According to these studies a strategic learner will adopt either a deep or a surface approach to their learning depending on which they perceive will help them to achieve high grades. Their interest in content is driven by assessment demands and they use whatever learning strategy will maximise their chances of academic success (Entwistle & Ramsden 1983, Watkins 2000). Strategic learners, in regards to his/her learning outcomes, exhibit a similar strategy to deep approaches but the focus is on short term performance and the intention to understand completely is usually missing from the student.

It has been argued that the strategic approach manifests in students as a result of the 'hidden curriculum' (Snyder 1971) which is where a student familiarises themselves with what the tutor expects from their students and sets about approaching the course in that manner. Biggs (1985) appears to agree with this in his description of the strategy behind the strategic approach to learning, stating the approach is to "follow up all suggested readings, schedule time, behave as 'model student'". According to Kember *et al.* (1999) the motive behind the strategic approach is based on competition and ego-enhancement: obtain highest grades, whether or not material is interesting. I chose Eley (1992) for a definition of the strategic approach to learning. He describes the strategic approach as consisting of:

> *"the intent to maximise performance and grades, allocating study time and effort in systematic and deliberate fashion, and adopting deep and surface strategies according to what is judged optimal and efficient for obtaining grades" (p. 231-232)"*

As can be seen from the above quote the emphasis in motivation for the strategic approach is on obtaining high grades but also one of the most significant elements of this approach is that the students choose between deep and surface. According to Richardson (1993) the following describes a student who adopts a strategic approach to their learning:

- intention to obtain highest possible grades;
- organise time and distribute effort to greatest effect;
- ensure conditions and materials for studying appropriate;
- use previous examination papers to predict questions;
- be alert to cues about marking schemes.

In the area of approaches to learning, a fourth less popular approach in the research has been put forward by Entwistle & Ramsden (1983) which they named ‘non academic orientation’. It is a description of students who exhibit low levels of motivation which results in negative attitudes and disorganised study methods. Entwistle later renamed it “study pathologies” (Entwistle 1991).

A study by Ellis *et al.* (2007) was based in a similar context to that described in this thesis and which also used a phenomenographic approach as its research methodology (for further detail see Chapter 3). In that study, they investigated the approaches to learning of pharmacy students in a problem-based learning environment. They used both an open ended questionnaire and interviews to develop their outcome space of approaches to learning within the problem-based learning environment which contained five separate categories which are illustrated in Table 2.6 below.

Table 2.6 Approaches to learning within the problem based learning environment of a pharmacy course source taken from Ellis *et al.* (2007, p. 684)

Category	Label	Deep/Achieving/Surface	Description
A	Resolving problems face-to-face using professional methodologies and judgement	Deep	Emphasises a need to use professional methodologies and judgement in order to fully understand the problem scenarios
B	Resolving problems face-to-face by contextually narrowing symptoms of patient in order to perform well	Achieving	Emphasises a deep strategy to understand the context of a patients situation with the main intention of performing well in the assessment of the case
C	Gathering information related to the problems face-to-face	Surface	Emphasises gathering information
DM:	Engaging in routine work face-to-face to solve problems	Surface	Emphasises routine work
E	Engaging face-to-face to develop generic skills	Surface	Emphasises a main purpose of gathering routine skills without being aware of their particular relevance to Pharmacy contexts.

The study's aim was to consider what the students think about problem-based learning (their conceptions), how they approach their learning in class (face-to-face) and how these are related to the marks they received (their academic performance). The study concluded that students who fell into category A performed at higher levels than the students in the rest of the categories. The researchers also concluded "that students who reported experiencing PBL as a way of rehearsing being a pharmacist, by gathering information from others and using database to find answers, tended to perform at relatively lower levels" (Ellis *et al*. 2007 p. 689). They also found no correlation between students falling into the achieving category and high performance. The study did not go into detail in regards to how they assessed performance outcome and merely indicated that students adopting a deep approach had performed consistently higher if only by a small percentage than surface students. Another study that examined approaches to study in a problem-based learning environment (Duke *et al.* 1998) in a nursing degree and found:

> *Approach A: Using One Resource only with Intention to Reproduce.* Responses in this category provided examples of surface learning where students aimed to reproduce content to meet subject requirements. Their approach was characterised by the use of only one information resource, ie. technology or human. Students identified some people such as peers, facilitators and/or clinical teachers whom they saw as having answers and canvassed them for information which would assist with reproduction of content.
>
> *Approach B: Using All Resources with an Intention to Reproduce.* Approach B responses also displayed a surface approach to learning but students indicated that they used both technical and human resources in order to assist with reproduction of information.
>
> *Approach C: Using All Resources Interactively with an Intention to Understand.* In approach C students used similar learning strategies to approach B. However, their method was interactive, that is, they discussed

answers and exchanged information with peers in order to review or revise conceptions and gain understanding. The students accepted that there was likely to be more than one answer and were able to tolerate this added dimension. Responses in this category seemed to reflect a deeper approach to learning than those of approach A and B in that students were using a wider variety of resources with the intention of broadening their understanding.

Approach D: Using All Resources Interactively Leading to Application with an Intention to Understand. These responses demonstrated that these students were also using a deep approach to learning albeit at a more sophisticated level. Students employed the same strategies as approach C but recognised the applicability of information to other situations, in particular the practice setting.

The first two approaches indicated are surface approaches with the emphasis on reproduction and no intention to understand while the C and D approaches seem to be two different levels of deep approaches both with the intention to understand. Approaches A and B differ only in the resources used to obtain the information to be reproduced. Interestingly approaches C and D show a progression in the position on Perry's scheme of cognitive development (section 2.3.10) as students adopting the approach move away from the belief that there is a single definitive answer from one source and see that there may be multiple answers. Moving away from problem-based learning environments and into a study of approaches to learning in a physics course. Prosser *et al.* (1996) examined first year physics students approaches to learning physics and found the following approaches:

- Category 1 – explanation based upon attendance and/or reviewing notes and/or learning formulas and/or doing exercise;
- Category 2 – response based upon seeking understanding – seeing how principles work, discussing with other students;
- Category 3 – response based upon relating to real world experiences, reading around the subject etc.

They concluded that in essence category 1 is a surface approach and categories 2 and 3 represented deep approaches. The differences between the two deep approaches would seem to be in the strategy they take to gain an understanding. Category 2 want to see how principles work which could possibly be interpreted as they wanted to understand how to apply understanding. While category 3 also intend to understand the material but through a relationship with real world experiences. Again the categories show similarities to the traditional approaches to learning but also differences with two levels of deep approach.

Another study that found unique approaches to learning was that of Case & Gunstone (2002) which was carried out in a chemistry context and which used a coding process. They found three qualitatively different and distinct approaches to learning:

- A conceptual approach where the intention is to understand the concepts;
- An algorithmic approach where the intention is to remember calculation methods for solving problems;
- An information based approach, where the intention is to remember information that can be supplied in response to assessment questions.

This time, the approaches to learning found for this environment could be construed to include two different levels of surface approaches. The intention of both the algorithmic and information approaches is to remember, in order to do well on assessment. Marshall (1995) using a combination of the Approaches to Study Inventory, ASI (see section 2.4.8) and interviews in an engineering foundation course also found distinctively different approaches to learning:

- Surface approach, in which students do not seek to establish relationships between material, learn by repetition and memorisation of formulae and simple algorithms with the intention to repeat these formula and algorithms in exams;
- Procedural deep approach, in which students relate formulas and algorithms to each other with the intention of gaining some

understanding at some future point through familiarity with applications of knowledge and problem solving procedures;

- Conceptual deep approach, in which students relate learning tasks to their underlying concepts or theories with the intention of gaining understanding.

Again, though the approaches above do seem to correlate in essence with the traditional approaches to learning, there are different levels of the deep approach. The majority of alternative approaches to learning research have frequently found approaches that are similar to the traditional deep and surface approaches but display different levels of the deep or surface approach. This is not always the case, Booth (1992) carried out research which examined students as they attempted to write a computer program and identified four different approaches to learning:

- Expedient approach, in which a previous program was identified which would suit the purposes of the given task;
- Constructional approach, where elements from previously written programs were combined to obtain a solution;
- Operational approach, which focused on what the programs were going to have to do;
- Structural approach, which focused initially on the problem rather than the program specifications.

In both the cases of the Case and Gunstone and the Marshall research studies, similarities can be seen between the approaches and the classic surface and deep approaches with slight differences because of contextual differences. Whereas Booth's study is much more functional in nature, in a learning environment where the main task is the construction of a computer program, it may not be possible to have anything but a surface approach. Although an argument could be made that, in terms of approaches to learning, 'expedient' could be related to surface and 'constructional' and 'operational' to strategic and finally 'structural' to deep the question arises of whether these relationships should be constructed or should they stand alone as they relate to their particular context. The above research projects show that deep and surface approaches may be fundamentally present across different subject areas, although not necessarily always, but in the application to a particular subject such as physics through problem-based learning the approaches may manifest in different ways or indeed other approaches may be present.

2.3.7 Memorisation versus surface approach

When memorisation is discussed as part of a deep approach it is normally in relation to the research pertaining to Chinese students who according to Biggs (1996) and Marton *et al.* (1996) tend to prefer memorisation, but do not simply adopt surface approaches to learning. Biggs (1996) indicates that Chinese students often see memorising and understanding as interlocking processes whereas the consensus in other research is that memorising is clearly distinct from understanding and should be considered as separate learning process (Sachs & Chan 2003). Marton *et al.* (1997) suggest that the Chinese learners experience of the relationship between memorisation and understanding is such that some

> *"See memorisation and understanding running in parallel, others think that the memorisation precedes the understanding and others again talk about understanding being a substitute for memorisation."* (p. 42).

Section 3.1 presents six conceptions of learning that the researchers point to as being a scale of development with learning by memorisation on the bottom. The students in this bottom level of the scale of development conceive understanding and memorisation to be intertwined but the more advanced students on the scale see them as separate entities. The perception that memorisation and understanding are seen as separate, is further reinforced by the implementation of Bloom's taxonomy (Bloom 1956) as a hierarchy in curriculum design. Kember & Gow (1990) believe that this mix of memorisation and understanding is in itself an approach which they described as "narrow orientation" and involves students having the intention to memorise and understand the material. Students adopting this approach systematically work through material section by section attempt to first understand and then memorise what they read. The reasoning behind students adopting this approach is indicated by Kember and Gow to be a combination of learning in English which is not the students first language, previous schooling and Confucian tradition and is not normally discovered in western students. It is worth noting that although memorisation is a key strategy when discussed in relation to a surface approach, it is rote learning (a mechanical act without thought of meaning) that is usually being referred to, as opposed to memorisation with the intent of seeking meaning which is what is generally considered as Chinese students approach to learning.

2.3.8 Methods of determining students approaches to learning

As indicated previously Marton & Saljo (1976a) and Ellis *et al*. (2007) both used phenomenographic methods of determining the outcome spaces of approaches to learning and the phenomenographic methodology will be described in detail in Chapter 4. While Biggs (1979), Laurillard (1979), Ramsden & Entwistle (1981) and Watkins (1983a, 1983b) all used surveys and interviews to confirm the presence of the original approaches in groups of students, these surveys and interviews were also based on the original Marton and Saljo approaches to learning. Case & Gunstone (2002) used an open coding and axial coding approach to ascertaining students' approaches to learning. They analysed interviews of their students and journals kept by the students for common occurring themes and then developed these themes into categories into which the students could be placed. As mentioned previously Biggs (1987a, 1987b) and Entwistle & Ramsden (1983) developed experimentally verified inventories to assess students' approaches to learning without the need for interviews. Although more expedient, this lack of use of interviews to find approaches means the inventories are assuming pre-defined categories. The research study in this thesis does not use either of the inventories, as I felt it was inappropriate to assume the presence of only deep, surface or strategic approaches to learning in a context in respect of which the inventories were not designed to assess. However, I do feel it is appropriate to discuss the inventories as they have both been major instruments in approaches to learning research in the last twenty five years.

The Study Process Questionnaire (SPQ) was based on the research of Marton and Saljo and uses a factor analysis which interprets ten scales in terms of three higher order factors of surface, deep and achieving. Students are asked to answer a number of questions, the answers to which refer to the ten scales which are then interpreted into one of the three approaches. Biggs is very explicit that the approach measured by the SPQ is a function of both individual characteristics of the student and the teaching context and so it is inappropriate to use the SPQ as a pre and post test for ascertaining whether a teaching intervention or innovation has had an impact. In 2001 Biggs (Biggs *et al.* 2001) published a new version of the SPQ espousing the need for an inventory that can be administered quickly so that teachers can more easily monitor teaching contexts. This newer version decreased from a three factor to a two factor of just surface and deep approaches. The high number of students scoring a surface approach gives evidence of the need for an intervention in the learning environment. The deep approach that the SPQ assesses is one that describes an approach towards comprehending the meaning of the materials to be learned, while the surface approach assessed describes an approach towards being able to reproduce materials for the purpose of academic assessment.

The Approaches to Studying Inventory (ASI) is similar in design and has been updated since its initial publication in 1994 (Entwistle & Tait 1994). However, mainly due to the time consumption of the previous iteration of the ASI this updated version of the instrument assumes too that the learning environment in which the questionnaire is being used does not contain students whose approaches to learning differ from deep or surface. The use of such instruments as the ASI or SPQ is based on Biggs (1987a) and Entwistle & Ramsden (1983) assumption that there is a cross situational consistency in learning orientation (approach) which is basically making the assumption that students from different disciplines are commensurable in terms of their approaches to learning and that the theoretical constructs embodied in the instruments possess empirical integrity in different cultural contexts and teaching contexts. This assumption contradicts Marton and Saljo previous assertion that learning outcome and approach to learning may differ between disciplines and this has been further supported by Meyer *et al.* (1990), Meyer & Watson (1991) and Eley (1992). But Meyer & Eley (1999) argue:

> *"That individual students might well adopt differentiated patterns of learning behaviours that are attributable to the learning contexts shaped by different subjects.*

That is, perceptions and experiences of learning contexts might be shaped also by the epistemology of a discipline and they might, therefore, vary considerably from one discipline to another." (p. 198)

Interestingly, Entwistle (1984) and Ramsden (1984) both have argued about the context dependency of approaches to learning but have also designed the SPQ.

Furthermore ASI research has found a clear contrast between experience in the arts and sciences. Watkins & Hattie (1981) found that:

"arts students were the most likely to show intrinsic interest in their course and to adopt a deep-level approach to their work. Scientific students tended to be relatively more motivated by vocational concerns and to adopt surface-level reproductive study methods." (p.392)

The question then might be asked as to how effectively these differences are accounted for within a generic ASI or SPQ. Going back to the question of memorisation and the paradox of students of a Confucian heritage, it is unclear how the ASI distinguishes between meaningless and meaningful memorisation (Watkins & Hattie 1981, Emilia & Mulholland 1991, Smith *et al.* 1998). Gijbels *et al.* 2008 also make a similar argument in regard to the questionnaires being designed for traditional learning environments and suggests they are not equipped to measure approaches to learning in a constructivist learning environment. For example, the collaborative aspects of learning, prominent in the learning environment of this study, are an essential part of this "new" learning environment, but are lacking in the SPQ. It describes studying essentially as a solitary activity affecting only the individual (Entwistle & McCune 2004) which would not be the case in a problem-based learning environment. Case (2003) investigated the validity of the use of such instruments in environments in which learning theory is introduced to students at some point before taking the ASI or SPQ. That study indicated that students become aware of the right answer on such inventories. The learning environment of this project includes an introduction to learning theory on induction day with the tutors referring to learning theories consistently so this argument may have some weight in the problem-based learning environment within which this research is situated. This awareness of the expected answer or the 'right' answer significantly affects the validity of these questionnaires.

Kember & Leung (1998) argue for an instrument to be valid it must be established that it actually measures what it purports to measure. The SPQ and ASI were developed using a relational perspective and so researchers using them in a specific context cannot purport to be measuring approaches to learning unless the instrument has been qualitatively assessed to measure approaches to learning in that context. That is not to say that all research carried out using such questionnaires is questionable. However, it is important to distinguish between the cases of adaptation of the questionnaires for particular contexts where qualitative research methods are used such as the interviews employed by the designers of the questionnaires and those who just adapt statements or rely upon validation studies conducted in different settings.

2.3.9 Factors that have been attributed to determining students approach to learning

This section reviews the many factors that have been attributed to having an influence on determining the learning approach of students. Research has shown assessment to be one of the major factors in determining a student's approach to their learning (Biggs 1973, 1989; Marton & Saljo 1976; Watkins 1983; Thomas & Bain 1984; Trigwell & Prosser 1991a; Ramsden 1988, 1992, Birenbaum 1997, Birenbaum & Feldman 1998) within a context. Assessment is often viewed as informing students what teachers really regard as important, however, Entwistle (1991) has indicated that it is not simply assessment or the learning environment that influence a student's approach to learning but that it is the students' perceptions of the learning environment and assessment that influences their approaches (see section 2.3.10).

Segers *et al.* (2003) argue that to achieve the aim of students having a deep approach to their learning in a new learning environment such as problem-based learning, the assessment should be aligned with the constructivist design of the course. In other words, the course should be constructively aligned, in that the learning, instruction and assessment should be aligned in order to produce the intended learning outcomes for the student.

Entwistle & Tait (1990) conclude that students who adopt a deep approach to learning prefer assessment procedures that support understanding and that assessment that focuses on factual information had a connection to surface approaches to learning. Interestingly, in regard to assessment, there is documented evidence that the use of multiple choice tests produces a surface approach (Adams 1964, Biggs 1973 and Thomas & Bain 1984) and that assessment procedures that emphasised factual information led students to adopt surface approaches to learning also (Thomas 1986 cited in Entwistle & Entwistle 1991, Entwistle & Ramsden 1983).

According to Biggs (2001) a student's approach to learning relates to both the students intentions and the teaching and learning environment.

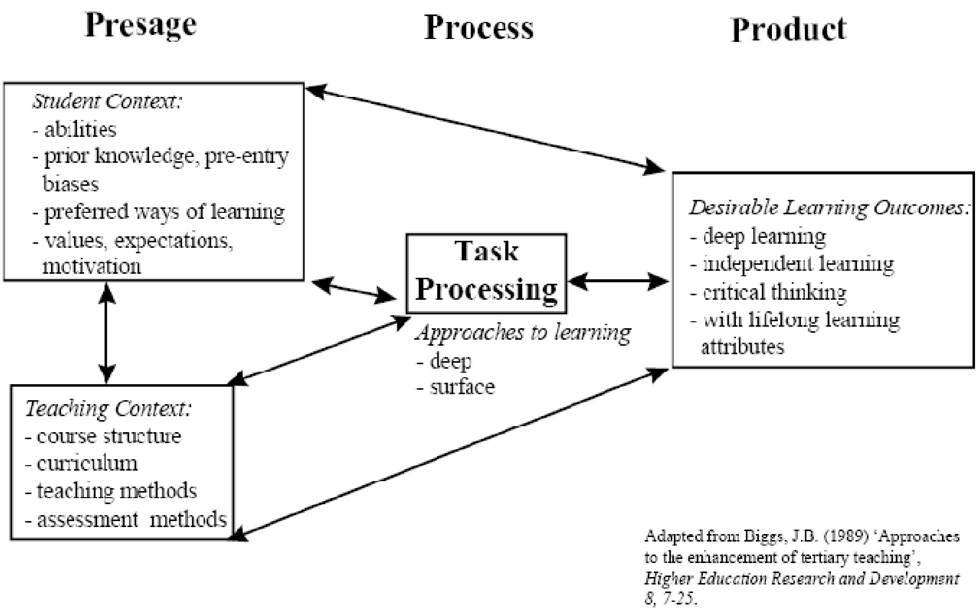


Figure 2.1 Bigg's 3P Model of learning source taken from Biggs (1989 p. 7-25)

Bigg's 3P (Figure 2.1) model of learning relates both student and teaching context with student approach and learning outcomes. On examination of the model and with reference to the research questions posed in this research project, it would seem that the boxes on the diagram represent answers to some of the research questions (what is the student's approach, what motivates the student) or information apparent before the beginning of the study (prior knowledge, teaching method) and the arrows represent the relationships which are the key questions in this research (such as what is the relationship between a students' approach to their learning in the context of problem-based learning and their learning outcomes). As indicated in the introduction, it was this model of learning that instigated the investigation of students' approaches and perception of the learning environment in an attempt to understand why students in problem-based learning were developing a greater conceptual understanding.

Along with assessment one of the other major contributing factors that determine a student's approach to their learning is the student's perception of the learning environment. Perceptions such as a high workload in the tasks that students are requested to complete or individuals having negative feelings towards working in a group have all been related to the use of a surface approach by students on many occasions (Kember 2004, Ramsden & Entwistle 1981, Entwistle & Ramsden 1983) and (Trigwell & Prosser 1991). Birenbaum & Rosenau (2006) found that the perception of poor teaching and poor student teacher interpersonal relationships resulted in students adopting a surface approach to learning. Beckwith (Beckwith 1991) also argues that it would be unfeasible that the educational philosophies, or approaches to teaching that the students perceived the teacher having, did not affect students' approaches to learning.

A link has also been established between teachers approaches to their teaching and students approaches to their learning. Trigwell & Prosser (2004) and Trigwell *et al.* (1994) found qualitatively different approaches to teaching and qualitatively different conceptions of teaching. A subsequent study by Trigwell *et al.* (1999) found that students are more likely to report that they adopt a surface approach to their learning in classes where teachers describe their approach to teaching as having a focus on what they do and on transmitting knowledge. Conversely, in the classes where students report adopting significantly deeper approaches to learning, teaching staff report adopting approaches to teaching that are more oriented towards students and to changing the students' conceptions. There are obvious parallels between approaches to learning and approaches to teaching research and figure 2.2 (Prosser *et al.* 2003 p. 39) indicates this parallel by observing the approach adopted by teachers is a result of the same factors that influences a student's approach to their learning.

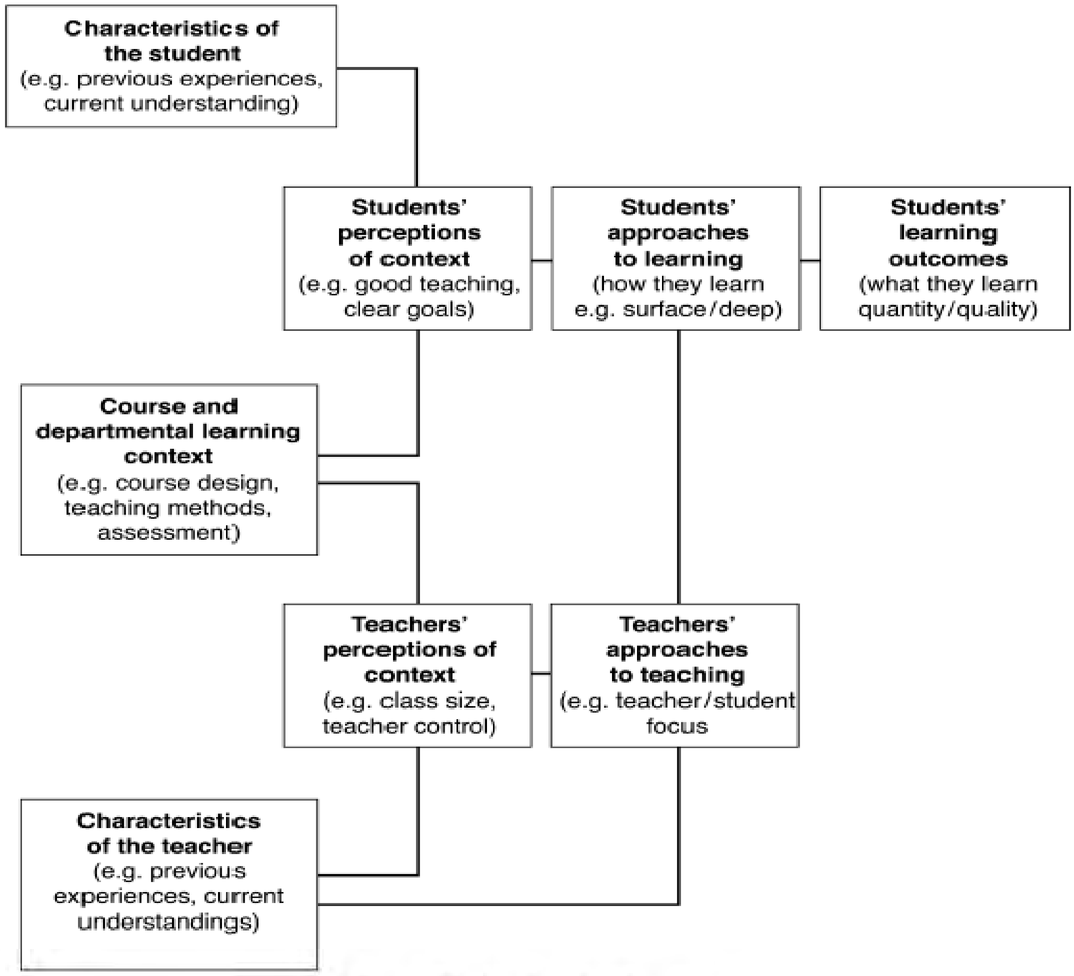


FIG. 1. Model of student learning.

Figure 2.2 Model of student learning, source taken from Prosser *et al.* 2003 p. 39

The relationship between approach to teaching and approach to learning may not be the same in the realm of problem-based learning. For instance previous research Gijbels *et al.* (2005) indicated that students did not perceive tutors as having an important effect on their approach to learning. This was asserted to be as a result of the course employing roaming tutors which is the same as the learning environment within which this research is situated. In another study by Ramsden (1983), which used an inventory called the Course Perceptions Questionnaire (CPQ) to evaluate two sets of students' (polytechnic and university) perceptions of teaching, he found that "an orientation towards meaning is more likely to be displayed by polytechnic students". He explained this by the fact that the polytechnic students perceived a higher vocational relevance of their courses and so were more intrinsically motivated than university students.

Entwistle (1987) also points to feedback on assignments and the provision of resource materials as components of a learning environment which influenced approaches to learning. Feedback has been attributed to encouraging a deep approach by a number of studies (Black & Wiliam 1998; Higgins *et al.* 2001) but others Hattie (1987) and Gijbels (*et al.* 2008) have indicated that the influence is not as profound as expected with little or no effect on converting student's to a deep approach. Pre-existing knowledge could also have an influence on a student's approach. Although Beckwith (1991) did find a correlation between pre-existing knowledge and course performance, by comparing the relationship between students' SPQ measurements and performance scores and scores on an exam of pre-existing knowledge, they did not however find any relationship between high pre existing knowledge and a deep approach to learning. Again this could be for a number of reasons such as the SPQ not being fit to assess approaches in the learning environment or the course not being constructively aligned in such a way that adopting a deep approach is rewarded.

Entwistle & Tait (1990) declared that the academic environment affects students' approaches to learning in four different ways. Firstly, that the level of performance obtained by a student in a course will affect their general attitude towards the course and those, in turn, effect the assessment the students take. Secondly, the academic environment can directly influence students' approaches to learning. For example, students having the perception that they have a lot of freedom in learning will most likely employ a deep approach to learning and congruently students who perceive a heavy workload are more likely to employ a surface approach to their learning. The third way is that students react to a commonly agreed perception of a learning environment. Therefore, if the commonly held perception of a learning environment is one that a surface approach will result in a better outcome on academic assessments, students will generally adopt a surface approach to that learning environment, that is if the students have a strategic approach. Finally in a course with students who have contrasting approaches to learning there will be a substantial relationship between students' approaches to learning and their perception of the learning environment. In the same paper Entwistle & Tait (1990) also state that the work a student carries out inside and outside of the classroom such as reading specified text books, background reading and carrying out various assignments are all part of the broader academic environment and so will also have an effect on the students' approaches to learning.

Other factors that have been attested to having an influence on a students' approach to learning is the time period at which studies took place. Research has indicated that the beginning of the student's degree course is a time of considerable intellectual and emotional uncertainty (Fisher & Hood 1987, 1988). O'Hanlon (1995) point out in their study, that there are transitional problems and an adjustment period associated with moving to a group-based learning environment, especially where former academic performances were obtained through individual success on a competitive basis. Powell (1973) and Miles (1981) discussed increased resistance, anxiety and uncertainty on the part of students in the early stages of small group learning activities. Other research evidence suggests though that, appropriately implemented, group work is associated with the adoption of deep approaches to learning (Ramsden 1992; Tempone & Martin 1999; Gordon & Debus 2002).

Research into the affect that the age of the student has on their approach to learning carried out by Zeegers (2001) found that the majority of older students generally displayed either a deep approach or achieving approach and not a surface approach but again this study was carried out using the SPQ. Of the SPQ subscales, it was the achieving strategy, deep strategy and deep motivation in which the older students had consistently higher scores; indicating that older students are more willing or able to commit themselves to the use of learning strategies which require a greater effort on their part. Various research studies by Watkins & Hattie (1981); Watkins (1982); Kember & Harper (1987); Scouler & Prosser (1994) and Richardson (2004) indicated similar results with Kember and Harper giving three reasons for 'mature' students' adoption of a deep approach:

- That mature students were motivated more by intrinsic goals (characteristic of a deep approach) than by vocational ones;
- That younger students acquired a surface approach to learning in the final years of secondary education;

- That the prior life experience of mature students promoted a deep approach towards studying in higher education.

As is apparent from the above descriptions of research into the factors that affect students' approaches to learning, there are a large number of influences that have been attributed to the type of approach to learning that students adopt. The majority of these factors are been investigated in some capacity in this research study through either the interviews or information gathered about the students. The next section focuses on one of the most significant factors, that of perceptions of the learning environment.

2.3.10 Students' perceptions of the learning environment

As was previously mentioned, a well held belief in approaches to learning research is that it is not the learning environment and assessment that influences a student's approach to learning but the student's perception of the learning environment (Entwistle 1987). Research by Ramsden (1987) and Thomas & Rohwer (1986) indicated that approaches adopted by students are relational, being both a function of the student and the students perception of the context (learning environment). Ramsden goes on to suggest (Ramsden 1988) that perception is the relation between the educational context and student experience. As a result of this assertion, Meyer (Meyer & Muller 1990) examined the inter-relationships between inventories measuring a student's approach to learning and his/her perceptions of the learning environment. This type of analysis resulted in showing how a group of students, relate their approach to their learning environment resulting in patterns of inter-relationships known as 'study orchestrations'. Trigwell & Prosser (1991) also carried out similar research and found a relationship between students' perceptions of the learning environment and the approach that they took. They found that a perception of high workload and rote recall assessment produced a surface approach and that perceptions of good teaching, clear assessment goals and learning independence resulted in a deep approach.

Biggs (2003) defines good teaching by presenting three interacting factors that have implications for learning: engagement, learning-related activities, and students' academic orientation. If the student perceives these factors to be orientated towards a surface approach this will influence them towards that approach. Case & Gunstone (2002) also debate this point by hypothesising that students would be more likely to adopt a conceptual approach if this message was received from all of the courses in their programme. Case and Gunstone, in the same study, further investigated students perceptions of the learning environment by focusing on one particular perception, that of students perception of time and found that students using different approaches appear to have, in many ways, similar perceptions of the context (in this case of the dominating time issue) with minor differences on how they act on these perceptions.

Richardson (1993), after a review of approaches to learning research, stated that the description of a surface approach or equivalent approaches are more variable and less coherent possibly because it is usually adopted as a consequence of students' perceptions that the learning environment is unsatisfactory. This will be manifested in different ways in different institutions or countries. Nijhuis *et al.* (2005) found that students' negative perceptions of different aspects of the problem-based learning environment have acted as a filter between the deep learning strategies that the environment is designed for and the actual learning strategies that the students employ.

Entwistle *et al.* (1991), Biggs (1985) and Scouler & Prosser (1994) have all presented evidence of students having confused perceptions of the learning environment and an apparent confused link between their perceptions of the learning environment and their approaches to their learning. They suggest that these students may not reflect upon their studies and may not understand their learning environment. While Calder (1989) found a 'surface confused' approach which encompassed students who appeared disorganised, anxious and unable to concentrate on their studies much like the 'non academic orientation' mentioned in section 2.3.6. Meyer & Muller (1990) asserted that deep approaches to learning are much more strongly linked to perceptions of learning environment than surface approaches. Students who adopt a deep approach are more aware of their learning environment and so the more aware they are of the environment, the more they can perceive it to be deep. So deep approach students have a tendency to be much more aware of the learning environment and what it entails.

An area of interest that relates to students perceptions of the learning environment is Perry's scheme of cognitive and ethical development. This scheme examines the meaningful way students construe the world of knowledge, value and education. The scheme which breaks down into nine positions of development is displayed in table 2.7.

The positions on the table are in essence student's attitudes towards knowledge and Perry (1970) claimed that college students journey through the 9 positions as they progress in college. Perry maintained that students can enter into college in any of the positions and that they can be in a variety of positions dependent on the subject and context. So a student could be in position 6 for Physics and 2 for Maths. On examination of the positions it is clear that a surface approach would be associated with positions 1 to 3 with students seeing teachers as the truth givers and movement up through the positions would lead to a deeper approach to learning. This cognitive development model will be discussed again in section 3.1 in relation to conception of understanding and section 2.3.11 in relation to meta-cognition and meta-learning. Finally with regard to perceptions of learning environment, in a number of research studies, students have been found to be able to perceive a need for a deep approach as the 'way to go' but do not know how to do it (Biggs 1996 and Minasian-Batmanian *et al.* 2006).

Table 2.7 Perry's Model of Cognitive Development (source adapted from Perry in Altbach 1997, p. 51)

Position	Description
Position 1 - Dualism/Received Knowledge – Basic Duality	Authorities know, and if we work hard, read every word, and learn Right Answers, all will be well.
Position 2 - Dualism/Received Knowledge – Full Dualism	True Authorities must be Right, the others are frauds. We remain Right. Others must be different and Wrong. Good Authorities give us problems so we can learn to find the Right Answer by our own independent thought.
Position 3 – Multiplicity/Subjective Knowledge - Early Multiplicity	Then some uncertainties and different opinions are real and legitimate temporarily, even for Authorities. They're working on them to get to the Truth.
Position 4 – Multiplicity/Subjective Knowledge – Late Multiplicity	Where Authorities don't know the Right Answers, everyone has a right to his own opinion; no one is wrong! Or In certain courses Authorities are not asking for the Right Answer; They want us to think about things in a certain way, supporting opinion with data. That's what they grade us on.
Position 5 – Relativism/Procedural Knowledge – Contextual Relativism	Then all thinking must be like this, even for Them. Everything is relative but not equally valid. You have to understand how each context works. Theories are not Truth but metaphors to interpret data with. You have to think about your thinking.
Position 6 – Relativism/Procedural Knowledge – Pre Commitment	I see I'm going to have to make my own decisions in an uncertain world with no one to tell me I'm Right.
Position 7 – Committed/Constructed Knowledge – Commitment	Well, I've made my first Commitment!
Position 8 - Committed/Constructed Knowledge – Challenges to Commitment	I've made several commitments. I've got to balance them-how many, how deep? How certain, how tentative?
Position 9 – Committed/Constructed Knowledge - Post-Commitment	This is how life will be. I must be wholehearted while tentative, fight for my values yet respect others, believe my deepest values right yet be ready to learn. I see that I shall be retracing this whole journey over and over – but, I hope, more wisely.

2.3.11 Meta-learning and Meta-cognition

In this section the ideas of meta-learning and meta-cognition are discussed as it has been reported in the literature that meta-learning is related to a shift in a student's approach to learning. This is important because Biggs (1985) suggests that students capacity to select strategies which are appropriate to the particular task reflects their capacity for meta-learning and describes meta-learning as making sense of one's experience of learning. Cloete & Shochet (1986) have found that the difference between successful and unsuccessful students is often not the study skills methods used, but whether the students are aware of why they are using a specific technique. Ramsden (1985) has argued that raising students' awareness of approaches to learning is an integral part of teaching and Entwistle (1987) argues that students may develop a deeper approach to learning through the application of meta-cognition. Meta-cognition involves two separate but inter-related processes. One of these is concerned with the students' own knowledge about their cognitive processes as well as an awareness of how compatible these processes are with a given learning situation. The other process involves the students being able to monitor their studying activities and making appropriate adjustments if they are not proving successful.

Weinert (1987 p.8) describes meta-cognition as "second-order cognitions: thoughts about thoughts, knowledge about knowledge, or reflections about actions". White (1998) identified four facets of meta-cognition (1) propositional knowledge about cognition (e.g. knowledge of factors that affect ability to memorise something); (2) awareness of one's own thoughts (e.g, monitoring one's understanding during a lecture); (3) Ability to regulate thinking (e.g., deciding what path to take while attempting to solve a problem); and (4) readiness/propensity to apply the ability to regulate thinking.

Meta-cognitive awareness is the ability to control or self-regulate our thinking and learning processes and products (Hartman 1998). Case & Gunstone (2002) make the argument that meta-cognitive development can be viewed as a shift in the approach to learning of a student. They also argue that meta-cognitive development can be identified as developments in students' conceptions of learning, improvements in the organisation of their own learning and a move towards self assessment and personal development with regard to views on the purpose of learning and long term career goals (Case *et al.* 2001). Biggs & Moore (1993) consider the constructs of approaches to learning and meta-cognition to be one and the same while Chin & Brown (2000) have also found notable links between students' approaches to learning and meta-cognitive activity.

Yager (2000) indicates that the characteristics of a classroom which intend to encourage meta-cognitive development are very similar to designs encouraged by constructivist classrooms. A course that is designed on the principles of constructivist learning theory with the intention of influencing students to take a deep approach to their learning is intrinsically linked with being meta-cognitively developing as well. One potential drawback of a course designed in this manner would be the assumption that students already possessed advanced meta-cognitive abilities and this may be an explanation for why some of the discovery learning methods fail to result in students taking a deep approach. In section 2.3.12, I describe 'learning to learn' programmes which are meta-cognitive in nature and were designed to bring about a change in a student's approach to learning and would help to counter any lack of meta-cognitive ability of students introduced to a discovery learning course.

2.3.12 Influencing a student's approach to learning

Van Rossum & Schenk's (1984) claimed that large numbers of students have, in the first phase of their study in a university, a reproductive conception of learning. As indicated in section (2.3.10) Perry modelled cognitive development and a reproductive conception could be an indication of being on position one or two of the model (i.e the lowest levels of cognitive development). Evans & Nation (2000) agree:

> *"Many students begin their university experience with a history of success through effective and instrumental learning strategies. They are unskilled and often unwilling to make the efforts to use tools and techniques that require them to think deeply and to collaborate extensively with peers". (p.31)*

Further evidence of this reproductive conception of learning at this time in students academic career comes from Australia in a study by Zeegers (2001) who describes the Australian secondary system as being targeted towards the very competitive university entrance procedure, which is based largely on results obtained in a state examination system. Such a system, from a student perspective, may appear to encourage rote learning as a means to success. In the same study, Zeegers references another unpublished survey that found that commencing tertiary education science students commented that they continued to use the same limited learning strategies at university as they had used in the past, as they see higher education as a continuation of their secondary studies.

Another finding reported in the literature is that students in most undergraduate courses become increasingly surface and decreasingly deep in their approach to learning (Biggs 1987a; Gow & Kember 1990; Watkins & Hattie 1985 and Zeegers 2001) which results in the conclusion that influencing a student to adopt a deep approach is difficult. It is worth noting, that again the majority of these studies would have used the SPQ or ASI as a basis for these results. Gow & Kember (1990) found the opposite result using a combination of the SPQ and semi structured interviews. In problem-based learning, Duke *et al.* (1998) found that prolonged exposure to problem-based learning resulted in a shift from surface approaches to deep. So then the question becomes how to affect a change in a student population towards a higher order approach. The feasibility of converting a student's approach to learning, to the higher order deep approach and the methods by which this conversion can be achieved, is a hotly debated topic in approaches to learning research. Going back as far as the original study by Marton & Saljo (1976b), attempts have been made at influencing a conversion from a surface approach to a deep approach.

In the 1976b paper Marton and Saljo describe an experiment to induce a deep approach to learning. Using reading tasks again, like they did in the 1976a paper, they separated a group of students into a group they designated deep learners and a group they designated surface learners. These students had not been interviewed prior to being put into groups and found to be deep and surface learners. Instead it was the intention of the experiment to promote the type of learning of the name of the group in that group. Each group had three reading tasks with the deep learning group being asked questions designed to induce deep level thinking and the surface learning group being asked questions designed to induce surface level thinking. After the third reading task the students were asked questions intended to measure surface and deep aspects of the contents they had just read. The findings found that influencing a deep approach proved difficult. The majority of the students, who were exposed to the questions that were to induce a deeper level of thinking, using the predictability of the task to develop an algorithm for learning to recall the text and summarise in one or two sentences a process. Marton and Saljo called this 'technifying' and saw it as a precursor to the strategic learning approach. Another interesting finding from this research was that students had preconceptions on what a reading task demanded and had used these preconceptions as they went about the task, i.e. these were students' perceptions of the learning environment.

Marton & Saljo (1997) found through their research that it was easier to bring about a surface approach than to induce a deep approach to learning and this was subsequently backed by Trigwell & Prosser (1991). Arzi & White (1986) found, training students to ask reflective questions resulted in students just giving modified replications of the questions they had been taught to ask. In many ways the Marton & Saljo (1976b) experiment is framed in the same way, when it proposes that by training students in answering deep approach questions they would then have a deep approach.

As is pointed out in section 2.3.11, meta-cognitive development can be matched to students taking a deeper approach to their learning and that the aim of this research project is to increase awareness of what a deeper approach might entail. Research by Hall *et al.* (2004) found an increase in students adopting a deep approach due to an increase in the use of deep strategies - reading widely, searching for relationships and integrating with previous knowledge without developing the intrinsic interest in the subject. Searching for relationships and integrating with previous knowledge if not previously displayed would be evidence of meta-cognitive development. Wilson & Fowler (2005), Biggs & Rihn (1984) and Dart & Clarke (1991) have come up with similar findings of students adopting deep strategies without the intrinsic interest in the subject with Wilson and Fowler concluding that learning behaviour is more amenable to environmental influence than underlying motivation.

In the past, research on approaches to learning in courses that have been specifically designed to induce deep learning through problem-based learning or courses designed under the influence of constructivist principles have had mixed success in inducing students to take a deeper approach to their learning. McKay & Kember (1997); Gordon & Debus (2002); Hall *et al.* (2004); Wilson & Fowler (2005) and Newble & Clarke (1986) have all been successful in transforming surface approach learners to deep approach learners with Newble & Clark (1986) and Dods (1997) finding a deeper approach to learning in medical education through the implementation of problem-based learning. Correspondingly, Gijbels & Dochy (2006), Groves (2005), and Struyen *et al.* (2005) found the opposite to be true, that students in their active learning environments in fact became more superficial in their learning and the number of students using a deep approach decreased. These studies are using inventories to measure approach to learning and as already discussed, it is inappropriate to use the SPQ or the ASI especially in an active learning environment like a problem-based learning course without first qualitatively evaluating the accuracy of the inventory for the environment. Also as Barrows (2000) has indicated for research to be prescriptive of the problem-based learning environment, the quality of the learning environment and the validity of calling it problem-based learning must be assessed.

Research by Nijuis *et al.* (2005) and Segers *et al*. (2006) found that students who were in a problem-based learning environment adopted more surface and less deep approaches to their learning. Case & Gunstone (2002) aimed to promote a deep approach by reducing the curriculum by 25%, introducing more active learning in the lectures, changing the assessment to be more conceptual in nature and introducing unlimited time examinations to facilitate students engaging with the concepts in examinations instead of focusing on working fast. They had some success shifting students from the “algorithmic approach” (surface) to a “conceptual approach” (deep). Another finding in previous research was that after an initial period of time spent in active learning environments there seemed to be no effect on the number of students adopting a deep approach (Mok *et al.* 2009), this is contradicted by findings from Duke *et al's.* (1998) research . Again, this lack of effect could be due to the way the approach was measured (SPQ) or more indicative that using an active learning environment is not enough without meta-cognitively developing the students as well.

An alternative to specifically designing course content to make taking a deep approach explicit to an academic task, is to use programmes such as the "learning to learn" as part of the course design (Martin & Ramsden 1987). Norton & Crowley (1995) developed two programmes designed to improve student learning called a study skills programme and a learning to learn programme respectively. A group of history students were split into two separate groups with each group attending one of the programmes. The study skills programme consisted of lectures on a set of study skills such as note taking, essay writing and some practical exercise and pointedly focused on skills separately from the curriculum. The learning to learn programme on the other hand was meta-cognitive in nature, focusing on structured group discussions which took into account the students approaches to learning and their perceptions of the learning environment while still covering the same basic skills of the study skills programme. Another difference in the learning to learn programme was that it attempted to directly link the sessions with relevant content within the curriculum. Their results showed a definite change towards higher learning conceptions as would be expected from the previous discussion of meta-cognition. Norton & Crowley (1995) carried out a similar study in the context of a psychology course and implemented a similar 'learning to learn' programme and they also found that students moved from an initially naïve conception of learning to a more sophisticated one by the end of the programme.

Case & Marshall (2004) bring up a very good point in regard to Marshall's course of foundation engineering in which the course objectives are aimed at students developing competency in basic skills. They raise an interesting question, should a deep approach be encouraged by the tutors, which may not be rewarded on assessments or should a more strategic or surface approach be encouraged with the danger being that students never apply a deep approach to similar situations where it is required.

2.3.13 The effect the approach by students has on their learning outcomes

In terms of the prediction of how well students will fulfil learning outcomes, research studies have drawn both positive and negative findings. Dochy (2005), Minbashian *et al.* (2004) and Trigwell & Prosser (1991) have all provided evidence that a deep approach does not necessarily result in students having profitable results in regard to learning outcomes. However, Biggs (1985, 1987a); Marton & Saljo (1984); Prosser & Millar (1989); Gibbs (1992) and Watkins & Hattie (1981) have all revealed positive relationships between deep approach and learning outcome performance. Similarly Marton & Saljo (1976); van Rossum & Schenk (1984); Trigwell & Prosser (1991); Ramsden (1992) and Prosser & Millar (1989) all have shown evidence that surface approaches to learning are related to lower quality learning outcomes. Thomas & Bain (1984 p. 237) though, assert that not taking a deep approach does not indicate that a student will not perform well on fulfilment of learning outcomes. They suggested that the following conditions of "subject relevance, opportunities to ask questions and clear assessment criteria" may help a student who adopts a surface approach to achieve good assessment results and that in an environment that encourages students to adopt a surface approach, the above conditions could enhance the effectiveness of the surface approach. This is dependent on the programme being constructively aligned, and that the learning outcomes are appropriate for a deep approach. The research and results described in this paragraph are all limited by the fact that the influence a student's approach has on their learning outcomes is dependent on the assessment being matched to the approach that is nurtured by the learning environment. So going back to the example of the Leaving Certificate or the approaches to the programming course (Booth 1992) for the surface approaches to yield higher levels of achievement on learning outcomes then the assessment must reward these surface approaches.

Van Rossum & Schenk (1984) have argued that a deep level approach and a constructive conception of learning are especially linked with a high quality academic outcome. In terms of longer term goals, not much research has been carried out on the effects of having a deep approach available to you over the course of your studies. But according to some researchers being a deep learner is a key element in being a lifelong learner (Birenbaum 2007 and Gijbels 2007). Previous research has also examined the relationship between students approach, perception and learning outcome with Meyer *et al.* (1990) having found that normally there is a coherent relationship between approach and perception but that this breaks down in relation to students that are failing. Prosser & Trigwell (1999), examining students with incoherent relationships between approach and perception, found that certain expected relationships occurred: e.g. perceived deep, approach deep, and who had a well developed understanding from their prior education achieved relatively high learning outcomes. But they also found that students with poor prior understanding, perception of a surface/deep environment and reported approaching their learning in both a surface and deep capacity had very poor learning outcomes. These students were labelled as having a disintegrated learning orchestration were a learning orchestration is the relationship between prior knowledge, perception, approach and learning outcomes. Hazel *et al.* (2002) found a similar group of students with a disintegrated learning orchestration. These students perceive the learning environment as being more supportive of deep approaches, but they do not adopt a deep approach. They also have the least developed prior understanding and have a lower achievement and understanding.

2.3.14 Arguments against approaches to learning

Approaches to learning research has been, for the most part, enthusiastically accepted by the education research community but there have been some criticisms of the theories involved. Haggis (2003) firstly has questioned the ‘generic’ nature of the model with the assumption that it can simply be applied across a range of culturally different disciplinary contexts as discussed previously (section 2.3.8). Other researchers have argued that the reification of the deep/surface model could result in it being prescriptive (Bock 1986; Webb 1997; Malcolm & Zukas 2001) as previously discussed in section 2.3.6. The previous statements have some weight in that a research project that assumes the presence of deep or surface approaches to learning before carrying out the research or by automatically relating the approaches found to deep and surface approaches is being presumptuous again as mentioned in section 2.3.6. As described previously in section 2.3.6 Booth (1992) and Case & Marshall (2004) found contextually independent approaches to learning in their learning environments. Marton & Saljo (1984) have in the past pointed out that the deep and surface approaches were noted in the context of a particular reading task and can in no way be presumed to be present in any other context without valid research.

The second point also has validity with Biggs *et al.* (2001) decreasing the number of approaches from three approaches to two and making the inventory shorter for teachers who want to assess the impact of their learning environment on their students. This is may be misrepresenting the contextual theory behind approaches to learning which could result in teachers looking for positive verification of the learning environment they provide with a questionnaire that does not take into account the subject and context of the students taking the test. Haggis (2003) also criticises what she sees as approaches to learning research viewing a student as some passive vessel that can be pointed in a deep approach direction. This again, I would argue, was covered in the meta-cognitive section of this literature review in which it was proposed that a student needs to meta-cognitively develop in order to undertake a deep approach to their learning or in regards to context, that the learning environment has to be adjusted in order for the student to adjust their learning approach. Therefore one can draw the conclusion that it is a choice a student must make whether it be a conscious or subconscious choice and that a change in approach can only be implemented by providing students with an environment to encourage a deep approach or give them information on what it means to make a choice about their approach to their learning or what it involves to take a deep approach. The latter is one of the aims of this research project. Finally, Volet & Chalmers (1992) argue against a surface-deep dichotomy and provide evidence of a continuum between the two. Students' approaches need to be located on this continuum at places appropriate to the task in hand. There are elements of truth to this assertion but again this can be remedied by carrying out qualitative research in your respective environment as opposed to blindly using an approaches to learning questionnaire.

2.3.14 Approaches to learning summary

The above review of approaches to learning research was completed to provide a solid theoretical basis for the research carried out. The following conclusions can be taken from the review:

- There are several commonly found approaches to learning – deep, surface, strategic and non academic and although in essence these approaches remain the same, specific important details may change from context to context as evidenced by the approaches portrayed in section (2.3.6).

- Students perceptions of the learning environment including assessment are one of the primary influences on students to their learning and there is an established relationship between a student’s approach and their perceptions of the learning environment. Other factors such as age of students and the transition from secondary to third level have also been found to influence students approach.

- In regards to learning outcomes deep approaches to learning are associated with high quality learning outcomes, while a surface approach is related to lower quality outcomes and there is a relationship between students perceptions of their learning environments, approaches to their learning and quality of learning outcomes.

- There is an established link between a teachers approach to teaching and students approach to learning.

CHAPTER 3

LITERATURE REVIEW – CONCEPTIONS OF UNDERSTANDING/LEARNING, PROBLEM-BASED LEARNING AND PHYSICS EDUCATION RESEARCH

3.1 Students conceptions of understanding and learning

According to Frazer (1992) and Gibbs (1992), understanding is a significant indicator of the quality of a student's learning. As understanding is one of the foundations and key learning outcomes of the problem-based learning environment, it is important to discuss students' conceptions of understanding. As part of the interview process that investigated the approaches of students to learning, the students being interviewed were questioned about their conception of understanding. So, in the context of physics, what does it mean to a student to understand a concept or phenomenon? In order to discuss any results pertaining to this line of questioning I must first outline previous research that examined students' conceptions of understanding. However, research in the area of conceptions of understanding seems to be intertwined with students' conceptions of learning, so both are discussed briefly. Students' conceptions of learning have been documented by the likes of Saljo (1979), Marton *et al.* (1993) and Crawford *et al.* (1994). Their research found various conceptions of learning, ranging from an increase in knowledge to an interpretive process aimed at understanding reality with the five different categories of description discovered by Saljo(1979) indicated below:

- Learning as the increase of knowledge;
- Learning as memorising;
- Learning as the acquisition of facts, procedures, etc. which can be retained and/or utilised in practice;
- Learning as the abstraction of meaning;

- Learning as an interpretative process aimed at the understanding of reality

In addition to the five conceptions of learning indicated above Marton *et al.* (1993) added a sixth:

- Learning as changing as a person.

These six are generally accepted conceptions of learning and it is also generally accepted that the six can be split into two different types of categories with the first three category points seen as attaining knowledge about something and the latter three seen in terms of developing an understanding of something. Similar research carried by Duke *et al*. (1998) investigated students' conceptions of problem-based learning. Duke *et al.* (1998), found four qualitatively different conceptions of a problem-based learning in a particular subject in an undergraduate nursing degree:

> 1: Process only - students expressed a conception that there was a process which was activity based but occurred in isolation of any learning outcomes. They did not appear to recognise the learning process as one which would lead to the development of knowledge and skill. Essentially they felt unsupported and isolated, viewing their learning as something they did either on their own or on their own within a group.
>
> 2: Process/Purpose (problem solving) - The listed comments describing the process were not linked to each other. The students attempted to satisfy the process requirements however, they also appeared to recognise that in doing so they were increasing their knowledge through problem solving. Whilst some students discussed working alone it did not appear to be an isolating experience.

3: Process/Purpose (Understanding/Contextualising) - In this category responses were seen to be relational, that is students linked aspects of the learning process together in order to understand and solve real-life cases. Students were involved in the learning process in order to problem solve. Through this process students were becoming aware that understanding will help them to solve real life problems.

4: Process/Purpose (Understanding/Contextualising/Applicability/Personal Objectives) - In this category the students discussed the relationship between the learning process in the classroom and the clinical setting, their own learning needs and professional applicability of the learning process in a relational way.

These four conceptions of problem-based learning are students conceptions of how they learn in the problem-based learning environment. Due to the nature of the environment, these conceptions of learning seem to be more complex than just conceptions of learning and instead they could be described as conceptions of the problem-based learning environment. Prosser clarifies (Prosser 2004):

> *"the term perceptions is used to refer to the experience of something in the external environment or context in which students are studying; for example, a particular assessment task. The term conception refers to the experience of something, which is abstract, for example, mathematics" (p.54)*

Conceptions of a subject has been indicated to affect students approach to learning. For example, Minasian-Batmanian *et al.* (2005) presented results that indicated fragmented conceptions of a subject will result in a surface approach. While students with more comprehensive conception of the subject will adopt a deep approach. It is obvious in the conceptions presented above that there are two distinct levels of conceptions with 1 and 2 being lower level compared to 3 and 4. According to Trigwell & Prosser (1997b) lower level conceptions of learning are limiting:

> *Without the ability to conceive of learning as being more than a quantitative increase in knowledge, or memorising, students will have extreme difficulty in adopting practices that lead to high quality learning (p. 243)*

One of the key design features of problem-based learning courses is that they are constructively aligned. Prosser (2004) argues that students do not always understand this alignment. Another key design feature of the problem-based learning course is learning through discussion but again Ellis *et al.* (2007) indicated that if students do not understand how discussion can help them to learn and understand they will not approach discussion in a deep manner. Ellis *et al*. (2006) found the following conceptions of learning through discussion and are included in this review due to the prominence discussion takes in this learning environment:

1. discussions as a way of challenging ideas and beliefs in order to arrive at a more complete understanding;
2. discussions as a way of challenging and improving your ideas;
3. discussions as a way of collecting ideas;
4. discussions as a way of checking your ideas are right

There is an obvious distinction of sophistication in these conceptions with 3 and 4 being less sophisticated than conceptions 1 and 2. 3 and 4 are more about checking ideas while 1 and 2 display an awareness of the understanding that can result from discussion.

It is important to indicate that what may count for understanding in one subject may not count for understanding in another. The paper by Newton *et al.* (1998) indicates that there are differences between conceptions of understanding in science students and history students. The paper also went on to describe two different conceptions of understanding of science students:

- Understanding as a capability in application
- Understanding as establishing a mental structure (which is inclusive of capability in application)

In a similar paper by Waterhouse & Prosser (2000) they present a table (table 3.1 below) of conceptions of understanding of physics students' (from various levels of study) that was constituted through a phenomenographic research approach.

Table 3.1 Students conceptions of understanding taken from Waterhouse & Prosser 2000 p. 6

Cat	Description	Awareness	Explanation
A	no physical description	focus is on the undifferentiated whole	understanding is seen as given, no effort required
B	understand when you can solve problems	focus is on the undifferentiated whole in relation to what the student perceives	understanding is when students know they can solve given problems
C	understand when you can relate to real life situations	focus is on differentiated objects in relation to what the student perceives	understanding is when you can apply what you know to real life objects
D	understand when you can explain it to others or yourself	focus is on differentiated objects in relation to what the student experiences	understanding is when you feel confident with explanations of objects
E	understand when you consolidate your knowledge	focus is on integrated phenomenon in relation to what the student experiences	understanding is when you feel you know the phenomenon deeply

The above table illustrates a hierarchical conception of understanding with "understanding as given" at the bottom of the hierarchy. This conception of "understanding as given" relates back to Perry's model of cognitive development (section 2.3.10) which has knowledge/understanding being provided by authority figures as the lowest position of cognitive development. Understanding as the ability to explain is much higher in the hierarchy than the application of understanding to real life. Although this does make sense in that to be able to explain something in the abstract is much harder than applying it to a realistic scenario but this may be dependent on the type of explanations of understanding that are given. In the realm of physics, an explanation may involve the description of a real life scenario to explain your understanding or an explanation of understanding may merely be the repetition of definition. The highest level of the hierarchy is the integration of phenomenon in relation to what the student experiences which would seem to have non-dualistic learning theory overtones. Helmstad (1999) in his thesis titled "understandings of understanding" discovered three separate conceptions of understanding:

- A reception of new knowledge either through observation or information.
- An acquisition of desired knowledge through relatively successful completion of deliberate learning activity.
- Realisation of a new truth on the basis of experience and interpretations of experience.

Newton *et al.* (1998) also indicate that difficulties for the students in the learning environment may develop due to differences between their conceptions of understanding and those of the lecturers. The lecturer may value concepts or methods of interaction that the student is not aware of. The relationship between students' conception of understanding and their approach to learning is discussed in more detail in section 3.2.

3.2 Relationship between approaches to learning and conception of understanding

A limited amount of research has been carried out that relates students' conceptions of understanding with their approach to learning, with many scholars indicating a link between the two but without investigating a specific relationship. Peers & Johnston (1994) indicated that students can differ widely in their ability to benefit from teaching that aims to develop understanding, as is the case in the problem-based learning environment. Perry (1970), addressing this point, postulated that in such learning environments these difficulties may arise from the students' views of knowledge itself and goes on to hypothesise that students' views about the nature of knowledge are related to their manner of studying. It is interesting to note that within teacher education it is widely accepted that epistemological views influence the way teachers teach and as stated in the previous sentence these same views can influence the way we learn/study. A study by Scouler & Prosser (1994) examined students' perceptions of the Australian Medical Council (AMC) Multiple Choice Questionnaire (MCQ) and found that students with a surface approach to studying for the exams perceived them as both examining understanding and factual recall. The authors found this confusing and suggested that these students did not have a "clearly conceptualised understanding of the concept of 'understanding’”. In the same study students with a deep approach were able to distinguish between understanding and factual recall. Similarly, Crawford *et al.* (1998b) found that students’ conceptions of mathematics are associated with their approaches to learning mathematics and their perceptions of the learning environment.

Significantly, Marton (1988) also acknowledged that some people are more likely to adopt a deep or surface approach depending on their conceptions of learning. Newton *et al.* (1998 p.50) also came to the same conclusion indicating that “an adequate conception of understanding for a subject is probably a necessary but not a sufficient condition to ensure that a deep approach to learning is adopted”. Helmstad (1999) in his thesis also comes to similar conclusions. He has indicated that performance of a learning activity that involves development of more advanced systematic understanding as an essential objective, requires relatively sophisticated understandings of understanding. Similarly in approaches to teaching research, Trigwell & Prosser (1996b) found that “teachers with sophisticated conceptions of teaching and learning see teaching and learning as a whole, while those with less sophisticated conceptions see only the parts” and that this research indicated that in order to change the way teachers approach their teaching, they need to change the way in which they conceive learning and teaching.

As indicated previously in section 3.1, Saljo (1979) found five categories of description for conceptions of learning and he thought it would be conducive to research in this area to test the assumption “that the fact that people employ either of these strategies (deep or surface approaches) has to do with their general conception of what knowledge and learning is” (Saljo 1979, p.21). This idea of choice or even ability to choose depends on students “meta-cognition” as discussed in the section 2.3.11.

3.3 Problem-based learning

3.3.1 Introduction

This section provides a review of the literature pertaining to problem-based learning. It details a comprehensive account of the history of problem-based learning through its inception, the reasoning for its introduction and its movement from medicine to other disciplines. The section also examines the epistemological underpinnings of problem-based learning and accounts for literature in relation to the type of thinking, conceptions and beliefs that problem-based learning encourages students to take when in the problem-based learning environment and, in turn, the intended thinking, conceptions and beliefs of teachers implementing this method of teaching. It reviews previous research on frequent topics of interest in relation to problem-based learning in the areas of tutors, assessment and group behaviour. The review concludes with a history and description of problem-based learning in DIT and, this includes the learning goals, assessment criteria and the implementer's conception of learning and teaching. The review does not include traditional group research as I found the problem-based learning research was inclusive of the elements of group research that are pertinent to this research project.

3.3.2 History and description as a pedagogy

Problem-based learning, as a specific pedagogy or teaching approach, was developed in the late 1960s in McMaster University to enable medical students to apply and synthesise knowledge through the use of 'real life' case studies (Boud & Feletti 1997; Barrows & Tamblyn 1980). In the 1970's Michigan State University and the newly formed Maastricht (Netherlands) and Newcastle (Australia) universities also developed problem-based learning courses. From this point, more medical schools began to implement problem-based learning within their courses or establish curricula that included some form of problem-based learning. Hoffman *et al.* (2006) reported that eighty percent of U.S. medical schools report they use some form of problem-based learning (although each schools definition of problem-based learning can differ greatly). It has since gained in popularity across diverse subjects such as law, business studies; engineering, medical/healthcare, architecture, economics, geology, social work and psychology (Woods 1994; Milter & Stinson 1995; Gijselaers 1995; Clouston & Whitcombe 2005; Alavi 1995; Allen *et al.* 2001; Donaldson 1989; Maitland 1998; Garland 1995, Smith & Hoersch 1995; Heycox & Bolzan 1991, Reynolds 1997, Pawson *et al.* 2006, Chu *et al.* 2009). Problem-based learning has been implemented in physics in the last ten years (Raine & Symons 2005, Van Kampen 2004, Duch *et al.* 2001) and was implemented in the DIT physics courses in 1999 (Bowe & Cowan 2004) although elements of it have been used throughout the physics community under the name of co-operative learning for a longer period of time (Heller & Hollabaugh 1992).

Barrows in an overview paper on problem-based learning (Barrows 1996 p.4) describes the motivation for developing the problem-based learning approach in McMaster University as he refers to the fact that the "McMaster group noted that the students were disenchanted and bored with their medical education because they were saturated by the vast amounts of information they had to absorb, much of which was perceived to have little relevance to medical practice". This directly led to "my design of a method of stressing development of the clinical reasoning or problem solving process for the neuroscience unit of the McMaster curriculum" (Barrows 1984 p.19). He was looking for a method of delivery that would link the education with the professional practice that they would eventually receive in medical education.

With regard to a description of problem-based learning as 'pedagogy' as its creator himself in his 1986 paper (Barrows 1986 p.484) states that "All these approaches to problem-based learning represent such a wide variety of methods that now the term has far less precision than might be assumed" or as Chen (1995) commented - the range of definitions illustrates how difficult it is to come to one universal definition. There is such a variety of what the educational community has considered as problem-based learning in the past that no one description will sufficiently describe the pedagogy. Instead the following segments give a description of the crucial elements of a problem-based learning course and details what is designed to occur in such a problem-based learning course. To begin with Barrows in his 1996 (Barrows 1996) overview paper describes the characteristics of his definition of a problem-based learning course and in it he states that under the McMaster model a problem-learning course should be comprised of the following characteristics:

- Learning is Student-Centred
- Learning occurs in Small Student Groups
- Teachers are Facilitators or Guides
- Problems form the Organising Focus and Stimulus for Learning
- Problems are a Vehicle for the Development of Clinical Problem Solving Skills
- New Information is acquired through Self-Directed Learning

In the same paper, Barrows (Barrows 1996 p.4) argues that all subjects in a problem-based learning programme should be taught using the problem-based learning approach stating that not doing so would "inhibit integration of those subjects (ones not taught through problem-based learning) in the students' understanding of a patients problem, it also requires students to move in and out of different learning approaches". This problem has been referenced in section (1.2).

In a paper by Dolmans (2005, p. 734), she describes problem-based learning in relation to its vital characteristics: "Although problem-based learning differs in various schools, three characteristics can be considered as essential: problems as a stimulus for learning, tutors as facilitators and group work as stimulus for interaction". Different approaches can be put forward to tackling learning issues or the use of student roles to stimulate interaction but these are often subject specific and the implementation of problem-based learning comes down to the use of the above mentioned essential features. Typically, problems are written "to guide students towards certain subject matter" (Schmidt & Moust 2000, p. 2) and "A problem usually describes some phenomenon or events that can be observed in everyday life, but can also consist of the description of an important theoretical or practical issue" (Schmidt 1983a p.14).

Problem-based learning as it was envisaged by its creator Barrows (1986, p. 483) must have certain characteristics but Barrows also argues that there must be certain inherent aspects in the way the problem-based learning programme is implemented to be considered to be problem-based learning pedagogy:

> *"A collection of carefully made problems are presented to smaller groups of students. Problems are usually descriptions of observable phenomena or courses of events that have to be elucidated or explained. Through a structured work process students formulate preliminary explanations to the phenomena, and link these to underlying theories or processes. The tasks of the groups are to perform the work process, to formulate what aspects of the initial problem they want to study, and to define their learning goal for the self tuition that follows. After this, tutorial groups meet again and give shared or joint account of the knowledge acquired, and finally "solves" the problem. Students and their tutor evaluate each meeting regarding learning processes in relation to goals of the actual theme."*

Along a similar theme Cockrell *et al.* (2000) identified that problem-based learning has six basic steps (a) encounter with the problem, (b) free inquiry, (c) identification of the learning issues, (d) peer teaching, (e) knowledge integration, and (f) problem solution. This would also describe how each group progresses through each problem in the DIT problem-based learning course (Bowe 2004). A detailed description of the basic steps that students take in the physics problem-based learning course is provided in a later section.

There has been a more recent debate on the stringency of inclusion of Barrows inherent aspects with Savin-Baden & Howell Major (2004) arguing that problem-based learning should not be defined by such limiting aspects and favour a more flexible view of the pedagogy. Savin-Baden (2008) describes different modes of problem-based learning depending on the context and subject in which problem-based learning is to be implemented in. Charlin *et al.* (1998) argue that differences between problem-based learning curricula can be found over ten dimensions: problem selection; problem purpose; student versus teacher control; nature of task; presentation of problem; problem format; process followed; resources used; role of tutor and outcomes assessed.

3.3.3 Theoretical underpinnings of problem-based learning

Moust *et al.* (2005) states that problem-based learning is a contextualist, collaborative and constructivist learning environment. Modern cognitive theory asserts that learning needs to be an active constructive cognitive experience that encourages students to build on what they already know from their previous knowledge. It should be student-centred and encourage students' to take full responsibility for their own learning. This modern cognitive theory is based on Vygotskian concepts and problem-based learning is in turn based on these Vygotskian concepts and modern cognitive theory. Vygotsky (Vygotsky 1978) defines learning as the social construction of knowledge and states that students should perceive themselves as the constructors of knowledge from a collaborative learning community. By acquiring new knowledge and restructuring their existing knowledge, individuals with differing opinions, experiences, and levels of knowledge about a particular subject engage in testing, retesting, and forging a new shared understanding of that topic through interaction with one another.

A primary rationale for instructional strategies that support the cooperation between learners is that such strategies more closely approximate the "real world" than traditional approaches. That is, activities requiring cooperation among individuals reflect how tasks are usually accomplished in practice (Vygotsky 1978). This also reflects another underlying cognitive theory on which problem-based learning is based, i.e., that knowledge obtained in a meaningful context or situation is more easily accessed due to the context being stored with the knowledge in the same cognitive structure (Norman & Schmidt 1992).

Another aspect that relates to the construction of knowledge and the students who partake in problem-based learning is the idea of ownership of knowledge. Cockrell *et al's.* (2000) paper describes a case study in collaborative groups in the problem-based learning environment, they mention that students "wanted to acquire a usable base of knowledge – to develop confidence or ownership in their learning". As a result, the course becomes more student-centred which is one of the ideals of all teaching strategies based on a constructivist epistemology and it also encourages an intrinsic motivation on the students part as they are more actively involved in the construction of their own knowledge. In turn, this encouragement of self directed learning is conducive to the students obtaining lifelong learning skills. In relation to group work being a stimulus to interaction, Dolmans (2005 p. 8) states that "The opportunity to discuss, argue, present and hear each others' viewpoints stimulates students learning".

When transferred to physics, the critical evaluation of other students' alternative conceptual understandings of a phenomenon by each other should, in theory, bring about the acknowledgement of misconceptions and the construction of a new conceptual knowledge that is a combination of all of the students understanding, with each student individually learning the concept in question and so resulting in a deep approach to learning. The previous sentence describes the presentation of conflicting conceptual views and this is another part of problem-based learning that is supported by social constructivist theory but also encouraged by Marton and Saljo's non dualistic theory (Marton & Saljo 1997). As discussed previously, there are many principles shared by social and individual constructivist theory but Savery & Duffy (1995) argue that when it comes to learning in the context of problem-based learning there are three principles underlying constructivism:

- Understanding comes from interaction with our environment;
- Cognitive conflict stimulates learning;
- Knowledge evolves through evaluation of the viability of individual understanding.

As problem-based learning originates from the constructivist view of human learning it is designed with these constructivist principles at its core. Camp (1996) points out that although problem-based learning has these constructivist principles as part of its design, it was, however, developed with medical students in mind who are often considered adult learners and so problem-based learning in its implementation form fits with the tenets of adult learning theory: "Student autonomy, building on previous knowledge and experiences, and the opportunity for immediate application are all known to facilitate learning in adults" (Camp 1996 p.1).

3.3.4 Criticisms of problem-based learning

3.3.4.1 Criticisms of problem-based learning based on human cognition theory

In a 2006 article in Journal of Educational Psychologist, Kirschner, Sweller and Clark (Kirschner *et al.* 2006) make an argument against minimal guidance instruction, specifically constructivist, discovery, problem-based, experiential and inquiry-based teaching. Minimal guidance is defined within the Kirschner paper as being defined as one in which learners, rather than being presented with essential information, must discover or construct essential information for themselves. They advocate the use of direct instructional guidance which they define as "providing information that fully explains the concepts and procedures that students are required to learn as well as learning strategy support that is compatible with human cognitive architecture" (Kirschner *et al.* 2006 p.75). Another important aspect of their argument is that they define learning as a change in long-term memory, so clearly their theory of learning is based on behaviourism. Their argument against minimal guidance is based on human cognitive architecture and the relationship between working and long term memory. They contend that "long term memory is now viewed as the central, dominant structure of human cognition" (Kirschner *et al.* 2006 p.76) and learning cannot be construed to have occurred unless there has been a change in long term memory.

With regard to working memory, they make the point that working memory has two well known characteristics when it comes to functioning with novel information, that it is both limited in duration and capacity. They indicate that in minimal guided instruction, the limits of working memory are ignored with the application of problem solving, for example, which has been proven to place a large burden on working memory (Sweller 1988) and that while the working memory load is processing the problem solving, it cannot contribute to the accumulation of long term memory and hence no learning will have occurred. Accordingly, this has a bigger consequence for (or impact on) the novice learner as they lack the proper schemas to integrate new information with their prior knowledge.

Kirschner, Sweller and Clark do not argue against the constructivist theory. Rather, they point to a fundamental error in assuming "that the pedagogic content of the learning experience is identical to the methods and processes (i.e. the epistemology) of the discipline being studied" (Kirschner *et al.* 2006 p.76). Kirschner (1991, 1992) makes the same argument when he contends that the way an expert works in his or her domain (epistemology) is not always equivalent to the way one learns in that area (pedagogy). After these articles there were several articles in response to many of the points argued in Kirschner *et al.* (2006). In their article Schmidt (2007) point out the many structures within the design of a problem-based learning course that address the issues of the limitations of working memory:

> *The PBL process aims to increase the interaction between knowledge already available in the learners and the new, to-be-learned information; elaboration by (self)explanations during group discussions stimulates the integration of new information into the knowledge base already present in long-term memory (Chi, Bassok, Lewis, Reimann, and Glaser, 1989; Pressley et al. 1992)(p. 93)*

They also argue that one of the main tenets of problem-based learning is that the tutors scaffold learning for student independence and that Kirschner *et al.* (2006) are misinterpreting the goal of student independence with novice learners being minimally guided or being unguided. Hmelo-Silver (2004 p.100) make a similar defence of problem-based learning and inquiry learning: "IL and PBL are not discovery approaches and are not instances of minimally guided instruction". This argument is rebutted by Sweller *et al.* 2007 pointing out that Barrows, one of the founding fathers of problem-based learning, continues to emphasise that problem-based learning be student self-directed. This seems to be the case as previously discussed (section 3.3.2) of multiple meanings of what constitutes problem-based learning and that Swellers rebuttal is merely an argument of semantics – why does one claim the students are self directed and then argue that there is direction through scaffolding their learning? It also may be a case of multiple degrees of the meaning of self-directed. It is also worth pointing out in relation to his particular argument that

Perry's cognitive model (section 2.3.10) of development argues that for students to develop cognitively they must become self-directed learners.

However it is the goal of any higher education programme to produce self-directed students, however, this does not mean that the learning is self directed, merely that the approach progressively encourages the students to be more independent by providing them with appropriate opportunities to direct their own learning. Barrows may feel that his students were ready, i.e. they had already developed these self directed skills. But it is worth noting that Barrows students have already completed a primary degree. The model of problem-based learning obviously has to be adapted depending on the students' abilities and development.

By simply giving the students a problem-based learning problem you are directing their learning, as the problem would be questioning a certain element of the course. Further scaffolding occurs through the tutors' line of questioning, mini just in time lectures (Hmelo-Silver 2004), and the structure of the problem solving that is given by the "four columns" (section 3.3.7). All these attributes challenge the students to allocate cognitive resources that will contribute to learning. Kuhn (2007 p.718) also indicates that "the structure of problem-based instructional activities may require the most complex and demanding instructional design of all" as another indicator of the structures put in place in problem-based learning courses.

> *Quintana et al. (2004) conceived of scaffolding as a key element of cognitive apprenticeship, whereby students become increasingly accomplished problem-solvers given structure and guidance from mentors who scaffold students through coaching, task structuring, and hints, without explicitly giving students the final answers. An important feature of scaffolding is that it supports students' learning of both how to do the task as well as why the task should be done that way (Hmelo-Silver, 2006). Extract from Hmelo-Silver et al. (2007 p. 100).*

Another failing of problem-based learning pointed out by Sweller *et al.* (2007 p.117) is that "cooperation or collaboration, however, imposes costs in terms of cognitive load in that the coordination and execution of communication and interaction in groups is, in itself, often cognitively taxing experience”. Schmidt (2007) counter this point by asserting that it is important to train students in the instructional technique in order to reduce any additional extraneous cognitive load that engaging in problem-based learning could result in (Clark *et al.* 2005). Schmidt (2007 p.93) also makes the point that the structure of problem-based learning instruction is a simple to complex design: “that makes optimal use of the reduction of intrinsic load with increasing expertise, allowing students to acquire knowledge in the simpler tasks that reappear in the more complex tasks”. One of the key skills sought for a problem-based learning graduate is the ability to learn, problem solve and work in a group concurrently and that although this can be taxing cognitively that does not mean it should be ignored as a method of learning. Sweller *et al.* (2007 p.94) finish their defence of their original article in regards to the detriments of problem-based learning with the following statement “PBL is ineffective compared with instruction that provides direct, explicit information”. This may be the case if the sole goal of the learning environment is the transfer of information but this dramatic statement is hugely amiss in its definiteness as Schmidt (2007 p.95) ascertains “it is important to note that the goals of PBL go beyond these kind of measures” of knowledge and knowledge application and Lawton (1980 p.175) states “evaluation must be concerned with the total context of an educational situation”.

Kirschner bases this rating of ineffectiveness on the papers by Berkson (1993) and Albanese & Mitchell (1993) which will be debated later as will that of Gijbels *et al.* (2005 p.33) who demonstrated very recently the positive effects of problem-based learning by making the contention that “a valid assessment system would evaluate students’ problem solving competencies in an assessment environment that is congruent with the PBL environment”. Again, this is going back to constructive alignment and aligning the assessment with the learning outcomes chosen by the course designers. Gijbels et al split knowledge into three different knowledge structures that could be assessed: (a) understanding of concepts, (b) the understanding of principles that link concepts and (c) the linking of concepts and principles to conditions and procedures for application. They found that when the understanding of concepts is the subject of the assessment, students in PBL perform at least as well as students in conventional learning environments. This is in line with the conclusion of Dochy *et al.* (2003) that the effect of problem-based learning is more positive when the understanding of the principles that link concepts is at the heart of the assessment as indicated in this physics problem-based learning environment by Walsh *et al.* (2009).

Silen *et al.* (1989) puts the aim of problem-based learning as to promote learning of how to formulate problems and to find proper information, how to apply the knowledge and how to evaluate one's own work. If Kirschner *et al.* (2006) do not include this as part of their evaluation of the effectiveness of problem-based learning then their contention that it is ineffective seems flawed. Sweller *et al.* (2007) and Kirschner *et al.* (2006) in their critique of problem-based learning seem to ignore some of the more positive aspects of problem-based learning such as the role that motivation plays in learning (Kuhn, 2007). As Polya (1963 p.610) puts it "for efficient learning, the learner should be interested in the material to be learnt and find pleasure in the activity of learning". One of the prominent positive aspects of problem-based learning is that students in many research studies have reported viewing what they were learning as having increased relevance, they got greater satisfaction with their learning environment and found it to be more nurturing and enjoyable (Moore 1989; Kaufman & Mann 1996; Blumberg & Eckenfels 1988, Bligh 2000, Norman & Schmidt 2000, Albanese & Mitchell 1993, Vernon & Blake 1993, Lancaster *et al.* 1997, Camp 1996).

Another defence against criticisms of problem-based learning, which is based on a meta-analysis of previous work such as Berkson (1993) and Albanese & Mitchell (1993), was provide by Camp (1996 p.3) puts it "is that so many different variations of PBL exist, from very "pure" to very "impure" and each variation is called PBL for the purposes of reporting the research". This means that both positive and negative results reported by such studies may be tainted by the inclusion of studies purporting to be problem-based learning. For example, some of the studies included could include papers that describe problem-based learning being adapted for one semester or for one subject area or in other cases it could be simply problem-based learning courses that have been implemented poorly. Another example could be a course where a tutor did not relinquish control of the learning environment to students and instead still did the majority of the talking and so was still trying to transmit knowledge through traditional methods. Finally, one of the most salient points in regard to rebutting the argument that "problem-based learning does not work" is to examine the absurdity of that statement. It would be the equivalent of saying "lecturing does not work", but of course it does as long as we are clear on its purpose, and in addition the effectiveness of the lecture will also be dependent on many other things.

3.3.4.2 Further criticisms of problem-based learning

Moust *et al.* 2005 point out some of the other frailties in a problem-based learning approach that they have found to occur after problem-based learning has been implemented for a number of years. They found that students tend to deviate from the original approach and brought in short cuts to the procedures in various ways. Sometimes students have brought in changes to the process of problem-based learning that interfere with their learning process such as not generating learning issues. Changes like this, when not reversed by their tutors, can have serious negative effects on their learning processes as well as learning outcomes. The Moust et al study also indicated an observed decline in self study time and preparation for tutorial groups and a reduction in the amount of time spent doing literature searches. The study also indicated that this decline can be explained by students' skipping or making their own interpretations of the steps involved in problem-based learning as will be discussed (section 3.3.7). Kirschner *et al.* (2006 p.82) also argues that "less able learners who choose less guided approaches tend to like the experience even though they learn less from it".

It can be argued, however, that these issues, are due to the problem-based course design or the implementation of the course and that in the case of Moust et al, problem-based learning was working but a certain amount of neglect occurred and allowed these inadequacies to manifest themselves. In the case of Kirschner, it could be argued also that those less able learners could have had the same results of not learning in a traditional environment but with the added attitude of disliking the environment just as students can dislike a learning environment and yet still achieve highly in it. It also ignores approaches to learning research that argue that motivation is one of the key influences on students taking a deep approach to their learning and, therefore, having a positive perception of the learning environment may motivate students of a lesser ability to approach the learning environment in a deep manner.

There are other criticisms that come from the medical education community and although they are medical education specific, are worth mentioning because of their reflection on problem-based learning. Kirschner *et al.* 2006 again points to Albanese & Mitchell (1993 p.52) when "they reported that although PBL students receive better scores for their clinical performance, they also order significantly more unnecessary tests at a much higher cost per patient with less benefit". Other criticisms from the medical education community point to the lack of evidence of students who have been educated through problem-based learning having better problem solving skills "PBL as an instructional strategy is unrelated to the learning of problem solving skills…the majority of problems in clinical medicine are solved through mental strategies that do not fit into the conventional definition of 'problem solving skills'…It is unlikely that the process of working through the problem adds to any repertoire of general problem solving skills" (Norman 1988 p. 283) and Berkson found no evidence for problem-solving skills being acquired better in problem-based rather than traditional curricula (Berkson 1993) with Colliver also arguing of there being "no convincing evidence for the effectiveness of PBL in fostering the acquisition of basic knowledge and clinical skills" (Colliver 2000 p.266). This could go back to Gijbels et al's argument that students are not being assessed on these skills or that reviews of research are not assessing for these skills.

Barrows argues (Barrow's 1996 p.8) simply "that in many problem-based learning curricula, the development of these skills is not addressed". Again though the main problem with all of this research, is that researchers are not comparing the same thing. It is like my previous point on traditional education, you cannot just evaluate a module or course that uses traditional methods and simply draw general conclusions about traditional learning – it simply makes no sense because of the various factors that could have affected this module or course (maybe the assessment was not aligned, maybe the lecturers were poor or the resources lacking, etc...).

3.3.4.3 Positive effects of problem-based learning

Having focused on criticisms in some detail in the above section, I think it is important to focus on some of the positive effects that have been attributed to problem-based learning. In my rebuttal of some of the arguments above, I have already indicated some of the positive influences problem-based learning has had on students. As with some of the criticisms above, most of the reports conveyed below belong to medical education and as the Albanese & Mitchell (1993) paper has been used with a high enough frequency to criticise problem-based learning it should be said that it also presented positive results. Students also reported viewing what they were learning as having increased relevance and having a greater satisfaction with their learning environment (Moore 1989; Kaufman & Mann 1996, Blumberg & Eckenfels 1988, Bligh 2000, Albanese & Mitchell, 1993, Vernon & Blake 1993, Lancaster *et al.* 1997, Camp 1996).

Problem-based learning encourages active, student-directed effort, develops professional communication skills, fosters the development of lifelong learning habits. The primary advantage of PBL however, is that it was developed specifically to enhance clinical problem solving (Schwartz *et al.* 1992). Distlehorst *et al.* (2005) reported significantly better combined clerkship performance for students completing a problem-based learning curriculum. Problem-based learning format improved the students' performances on tests of knowledge application in comparison with a more traditional curricular format (SI) (Hoffman *et al.* 2006). Norman & Schmidt (1992 p.559), reported "that students in a problem-based curriculum integrate their knowledge better than do students in a traditional curriculum, which means that the former students can solve problems more effectively".

With regards to approaches to learning and meta-learning which has been previously discussed, Moore *et al.* (1994) and Lieberman *et al.* (1997) reported a specific decreased reliance on rote memorisation and greater reflection on the material they learn and how they learn (Moore *et al*. 1994, Lieberman *et al.* 1997). Norman & Schmidt (1992 p.563) argued that “students in a problem-based curriculum actually acquire more self directed learning skills than do students in a conventional curriculum and this difference is sustained beyond the duration of the curriculum”. Students in a problem based curriculum made greater use of the library and self-selected reading materials and felt more competent in independent information seeking skills (Rankin 1992, Blumberg & Michael 1992, Saunders *et al.* 1985). Margetson notes that problem-based learning potentially fulfils Biggs’ four crucial criteria for a deep approach to learning: a well structured knowledge base, learner activity, learner interaction, and motivational context (Margetson 1994) with some other researchers reporting a deeper approach to learning with problem-based learning (Coles 1985, Newble & Clarke 1986).

Research has also indicated that problem-based learning have a positive influence on lifelong learning skills and long term recall. Martensen *et al.* (1985) demonstrated that students in a problem-based learning course showed no difference in short term recall but a significant advantage in long term recall. Tans *et al.* (1986 p.42) found that “students under the problem-based learning condition recalled up to five times more concepts than did the control group”. There is evidence that problem-based learning supports the development of reasoning skills (e.g., Hmelo 1998), problem-solving skills (e.g. Gallagher *et al.* 1992) and self-directed learning skills (e.g., Hmelo & Lin 2000). Problem-based learning methods are also effective at preparing students for future learning.

To summarise Berkel and Schmidt described the positive aspects as follows “learning is contextually valid….second, learning is cooperative. Students help each other and are rewarded for doing so (O’Donnell & King 1999; Pontecorvo *et al.* 1990). In addition, it is known that asking for explanations and providing them to peers enhances learning (Webb *et al.* 1995). Third, there are some indications that students actually learn to solve problems in a better way as a result of problem-based learning (Hmelo 1998). Fourth, problem-based learning appears to have a strong motivating effect” (Berkel & Schmidt 2000 p. 236).

3.3.5 Problem-based learning pro versus con summary

As can be seen from the above review of the literature pertaining to problem based learning there are numerous arguments for and against the pedagogy:

According to cognitive load theory, learning in a problem-based learning environment is more taxing due to the lack of structure given to students that result in less learning. The rebuttal to this is that learning in problem-based learning is structured through the problems and tutors. Problem-based learning is viewed as more taxing cognitively due to the self directed aspect of the environment, but should one of the goals of all third level course not be to produce lifelong self directed learners. An argument was proposed that the cooperative element of the course results in extraneous cognitive load. Although this may be true, any extra cognitive load could be reduced by training students to work in problem-based learning but also it is the skills picked up by learning cooperatively that is one of the main aims of problem-based learning. It was argued that direct explicit information is more effective than problem-based learning. This may be true if the singular intention of teaching is the transfer of knowledge but that is not the case in problem-based learning. The ineffectiveness of problem-based learning has been evidenced by poor results in learning outcomes in several papers but again this finding may be incorrect due to the transfer of knowledge not being the only learning outcome. A number of these papers include problem-based learning courses that would be considered poorly designed learning environments. In conclusion the majority of arguments against problem-based learning can be attributed to a limited view of learning outcomes, or the inclusion of learning environments that are designed by teachers who have limited conceptions of teaching that are not aligned to student-centred learning.

3.3.6 Problem-based learning research

3.3.6.1 Problem-based learning research introduction

Since its inception a large number of research papers and studies have been presented in regard to research into problem-based learning. Initially the papers originated from medicine but as the pedagogy was transferred and adapted to other disciplines, research began to appear in journals from multiple disciplines. The studies that have been conducted on problem-based learning groups have a tendency to fall into one of four areas of interest; (a) the role of the tutor, (b) the role of assessment, (c) group behaviour within problem-based learning groups and (d) problem-based learning problems. The following sections outline the research that has taken place to date on these four key areas starting with problem-based learning tutors.

Contained within Barrows' aforementioned characterisation of problem-based learning (Barrows 1996 p.8) is his description of the role of a problem-based learning tutor as "… someone who did not give students a lecture or factual information, did not tell the students whether they were right or wrong in their thinking, and did not tell them what they ought to study or read" and goes on to state that "It seems generally agreed now that the best tutors are those who are expert in the area of study, only they must also be expert in the difficult role of tutor".

The second statement without reference to any particular study or research directs us to one of the major focuses of many researchers: the tutor role in problem-based learning. This has attracted the interest of many researchers and has led to an abundance of literature from many different fields. According to (Schmidt & Moust 2000 p. 3), "The role of the tutor is to facilitate students' learning processes and to stimulate students to collaborate in an effective way" or according to Gijselaers (1996 p.13) "a tutor, whose role is to facilitate the learning process by asking questions and monitoring the problem-solving process" and expands later in the same paper on the role of the tutor “In the perspective of teaching metacognitive skills, a tutor asks questions that monitor the progress of problem solving action. This models the kind of questions that students should be asking to identify the nature of the problem and the kind of knowledge required to understand it. These questions also lead students from the concrete problem and toward conceptual knowledge.” The tutor has to skate a fine line between involving the students in discussing the issues and evolving this discussion to the critical learning issues without entering into the realm of a teacher centred approach of a multitude of questions and mini lectures. Wilkerson (1995) conducted a study in which medical students at Harvard University were asked to describe how tutors were helpful in problem-based learning groups and obtained four helpful behaviours of teachers:

- Balancing student direction with assistance;
- Contributing knowledge and experience;
- Creating a pleasant learning environment;
- Simulating critical evaluation of ideas.

Whereas Schmidt & Moust (1995) based their model on questionnaires completed by students after completing their course and they advocate three interrelated qualities of an effective tutor:

- An attitude of caring for and interest in the students;
- A knowledge base related to the learning objectives of the course;
- The ability to transfer this knowledge base into terms readily accessible by students.

Schmidt (1994) found that there was no relationship between tutor expertise and student achievement within the health science courses. Silver & Wilkerson (1991) point to the fact that tutors with more content expertise had a tendency to take on a more directive role in problem-based learning and that this could impede the development of students’ skills in active self directed learning. Whereas Moust *et al.* (1989) point out that the expertise of the tutors may be of greater benefit to students due to the quality of expert tutors interventions.

Barrows advocates that the ideal tutor is one who is expert both in the content of the course and in the tutoring process:

> *It is far better to have an expert working with the students, one who knows if the students are in a quandary or are going down the wrong track; but who also knows how to get them to discover this for themselves, to learn by making mistakes, and to reason their way to the right conclusions. Such an expert can provide the students with better evaluative feedback about their learning, relevant to their own objectives. (Barrows & Tamblyn p.106)*

Wilkerson (1994 p.308) points out that "for the purpose of tutoring, expertise may simply mean having knowledge about the specific case and what learning issues it is designed to raise".

Eagle *et al.* (1992) agree with this statement but also point out in their study that expert tutors have an effect on the number of, the congruency of and the amount of time spent on learning issues, with students who had expert tutors producing twice as much learning issues and spending twice as much time on them. Zeitz in (Anderson *et al.* 2003 p.3) comments, however, that the above points on tutor expert/non expert become redundant with the advent of students experience in problem-based learning, "students enrolled in a PBL curriculum are so acculturated and so highly skilled in student-centred, self directed learning that they begin to function independently of the tutor the vast majority of the time and begin to stop caring about the facilitators opinion as they begin to value their own work so highly". In summation on tutors and the expert/non expert question, there seems to be as many studies with positive reflections on non-expert tutors as there are against. However, this question does not have any real bearing on this study as all tutors were tutors with expert knowledge of the subject and there was no choice of having non-expert tutors.

Dolmans *et al.* (2001 p.886) argue that "tutor's performance is not a stable characteristic, but is rather situation-specific…the contextual circumstances shown to influence tutors' behaviour are the quality of the cases, structures of PBL courses, students' level of prior knowledge and the level of functioning in tutorial groups". In the same paper Dolmans et al tested the effects that group dynamics skills of a tutor had on the evaluation they received from the students. In this regard they presented data obtained from a questionnaire that they produced which indicated that tutors' group-dynamics skills did contribute positively towards the performance scores they received. Another area of research in regard to tutor performance is that of interventions, with some tutors finding it frustrating or difficult to know when to intervene. This problem is discussed by Maudsley (2002) who commented on the emotional difficulties of taking on a facilitation role, and Kaufmann & Holmes (1996), who, as a result of the observed difficulties, identified the need for further training in intervening appropriately. Finally, in regard to approaches to learning Moust *et al.* (2005 p.675) argue that the "tutor can have considerable influence on the developments of students' abilities as self directed learners". Tutors can help students gradually to master cognitive and regulative learning skills to become independent and lifelong learners". If tutors have an effect on the meta-cognitive development of problem-based learning students then they can also influence the development of approaches to leaning skills.

3.3.6.2 Problem-based learning assessment

Assessment has been shown to have an effect on determining a student's approach to learning and has been previously covered in the approaches to learning section of this thesis. This review of problem-based learning assessment is aimed at examining how students in problem-based learning have been assessed in the past. In particular, reviewing research on self assessment which is used as an assessment method in the problem-based learning course in which my research project is based. Problem-based learning, as previously described, is directed towards producing highly knowledgeable individuals who have problem solving skills, professional skills and who learn in real life contexts. According to Dochy & McDowell (1997 p.283) it "demands an adaptable, thinking, autonomous person who is a self regulated learner, capable of communicating and co-operating with others and so students should be assessed on such skills and competencies". The assessment of the problem-based learning course is examined in the section on problem-based learning in DIT but assessment of individual performance in the problem-based learning sessions comes in the form of tutor assessment for the first half of the year and collaborative assessment for the second half of the year.

In an investigation of the agreement of tutor assessment of students participating in problem-based learning assessment Schor *et al.* (1997 p.150) demonstrated that "given specific criteria by which to judge students' performances, it is possible to arrive at consistent, non–idiosyncratic grades for students in PBL courses." Some of the findings in research into the effects of self assessment include Falchikov & Boud (1989) discovering that good students tended to underrate themselves and those weaker students' overrated themselves and also found that there was no discernable difference to how students evaluated themselves as they progressed through their college years. Longhurst & Norton (1997) found that motivation influences the accuracy of self assessment and, as noted elsewhere in this review of problem-based learning literature, the problem-based learning environment results in highly motivated students.

Adams & King (1995) argue that like group learning skills, self assessment skills should be developed before use. They outlined a three level approach starting with the students working to understand the assessment process. Secondly, the students should work to identify the important criteria for assessment and thirdly students should work towards playing an active part in identifying and agreeing assessment criteria and being able to assess peers and themselves competently. Dochy *et al.* (1999 p.337) concluded "that research reports positive findings concerning the use of self-assessment in educational practice".

In the concluding remarks by Dochy *et al.* 1999 the authors state:

> *"That there is much evidence which supports the view that students' contributions to assessment can be consistent with the assessment of staff, and of other students. There is also empirical evidence that the students perceive positive effects. Involving students in assessment is perceived as being valid, reliable, fair and as contributing to a growth in competence"(p.347)*

They proceed in the same paper to note that:

> *"One context in which these methods could be particularly useful is the problem-based learning environment. Peer and co-assessment are inherent aspects of working on problems within small tutorial groups"(p.347)*

3.3.6.3 Problem-based learning group behaviour and observation

Research that describes a method to gain an understanding of the group processes within problem-based learning is presented in a paper by Chiriac (2007) in which she advocates a method of analysing groups based on a combination of Steiner's (Steiner 1972, 1974, 1976) work on variables that affect group performance and Bion's (Bion 1961) theory of the professional work group. She created a theoretical table combining the activities that a group can undertake from Steiner's research with Bion's descriptions of how a group is acting (in other words the group mentality) and used this table to analyse problem-based learning groups in action. Chiriac (2007 p.505) found that "it is possible to give a comprehensive and descriptive picture of the group processes that occur in tutorials" and produced a table (Table 3.2) of the dynamics found in the tutorials.

Table 3.2 A theoretical combination of Steiner's and Bion's theories source taken from Chiriac (2007)

Type of activity	Work group	Dependence group	Fight group	Flight group	Pairing group
Additive					
Disjunctive					
Conjunctive					
Compensatory					
Complementary					

Table 3.2 is a combination of the emotional state of the group (i.e work group or flight group etc.) and the type of activity that the group is involved in (additive or conjunctive etc.) A group could be observed and table 3.2 could be used to interpret the observations of the group over a time period. For a full description of both the emotional states and the types of activities see Appendix C. Chiriac's research is similar in theme to the research being presented in this thesis in that its emphasis is in finding out exactly what is going on within the groups during problem-based learning sessions. However, it differs in focus as Chiriac's research is looking at the group as a whole whereas the research presented in this thesis is looking at the individuals within the groups and their respective approaches and actions within a problem-based learning group. Another study that focused on group processes within problem-based learning is Tipping *et al.* (1995) in which they investigated

tutorials using post tutorial questionnaires and videotaped observations. The study revealed that both students and tutors were unaware of what would constitute effective group dynamics for a group nor was there a means to encourage the students to engage in self reflective behaviour that could help them analyse their behaviour with the purpose of improving group dynamics. The Tipping *et al.* study also pointed to a discrepancy in the self reported behaviours of both students and tutors alike and that the students showed no evidence of reflecting on any aspect of the groups' behaviour nor did they have the awareness to correct behaviour that was not conducive to group performance.

Glenn *et al (1999).* also carried out studies on group processes after videotaping students working in problem-based learning groups for five years. In one paper (Glenn *et al.* 1999) they examined the behaviour of students as they describe and formulate a theory that accounts for the evidence provided in the question. They hoped by evaluating this data that they would be able to illustrate some of the interactional sequences through which members of a group move as they evaluate, modify, and accept or reject theories. The study identified at least two organising frameworks or sequential contexts: group problem solving or decision making and teacher student interaction. In another article by the same researchers (Koschmann *et al.* 2000), they examined the interaction leading up to the generation of a learning issue. In particular, they examined the process of students' recognising and negotiating a learning issue. Although similar in aspects of execution and theme to this research project, the research described above examines the group processes leading to theories and learning issues, while the aim of my study is to examine the actions of individuals within the group and their approaches to learning within the context of problem-based learning environment.

Berkel & Schmidt (2000) attempted to model process characteristics of problem-based learning related to outcomes. They used a process method based around a model of input, process and output variables in which, for example, input variables to the problem-based learning process include the likes of prior knowledge, quality of problems used and effectiveness of tutor. Learning process variables included group functioning effectiveness, amount of time students spend on self directed learning and output variables included the resulting achievement and interest in the topic studied. In the study, students used a rating scale consisting of 42 Likert-type items covering the various dimensions (variables) previously mentioned and time spent on learning was assessed by asking the students to estimate the number of hours spent on learning issues per week and achievement being assessed by a 200 question true-false test administered at the end of each unit. Using a simple Chi-square and degrees of freedom analysis, a level of significance was measured as correlations between variables. Berkel and Schmidt (2000 p.231) found that "attendance is a important determinant of learning in problem-based settings…not only does attendance adequately predict academic achievement; it is itself predicted by the quality of tutorial group functioning". Their data went on to suggest that the better the groups functioned, the better attendance was and the higher the scores achieved on the final examination. Berkel and Schmidt also found that "the more the group attended, the less time needed to be spent on self directed study" (Berkel and Schmidt 200o p.231). Another finding from the study was that poor quality of problem usually led to a higher attendance at tutorials and that prior knowledge negatively influenced on students attendance.

Van den Hurk *et al.* (1999) developed a five point Likert scale, 23 question questionnaire which investigated the impact of individual study on tutorial group discussion. They found that "preparing the literature for the next tutorial meeting does affect the breadth of the reporting phase" (Ven den Hurk *et al.* p.197) but not significantly and that when students prepared the literature with the aim of explaining it to someone else "the breadth of the discussion will also be stimulated". Dolman's *et al.* (2001 p.886), also in discussing the effect of peer or self assessment or tutor assessment, discusses the effects this type of assessment can have on group behaviour "In our opinion, this solution also does not contribute towards diminishing the negative experiences, because some students might feel coerced to demonstrate behaviour in the tutorial group which can be characterised as artificial, to impress the tutor, rather than behaviour that can be characterised as being intrinsically motivated."

Dolman's study also indicates another group behaviour effect called 'ritual behaviour of students' that occurs in tutorial groups and which can discourage learning (Dolmans *et al.*

1999). Ritual behaviour is a description of a break down in the normal processing of a problem by a problem-based learning group which can occur for several reasons. The question is if this is an underdevelopment of learning issues at the start of the problem or prior knowledge incorrectly associated with concepts or students not doing work in-between classes. Dolmans *et al.* (2001) argues that teachers will revert to teacher centred solutions to try and solve the above problems hence moving away from the student-centred approach of problem-based learning and taking away students possession of knowledge and in turn the teachers blame the breakdown of learning on the approach. These problems may occur due to poor implementation of the problem-based learning approach, with tutors not stimulating discussion or the problems themselves not linking well with student's prior knowledge.

In Dolmans *et al.* (2001 p.886) paper, she identifies some of the positive cognitive and motivational effects that problem-based learning has on students who are taught using this approach. "From a cognitive perspective, PBL students are assumed to be more able to learn information, because of activation of prior knowledge and elaboration of newly required knowledge." Also from the cognitive perspective "PBL also induces cognitive conflict within students, leading to conceptual change or a restructuring of their knowledge base" and she points to a number of studies that have claimed such conceptual change (Norman & Schmidt 1992; Regehr & Norman 1996). In relation to the positive motivational effects, Dolmans points to the fact that students engaging in discussion on the subject matter will influence their intrinsic interest in said subject matter. She also points to the team spirit element of problem-based learning, with the group members caring about the group as they wish to see it succeed and points to some research on the effects of problem-based learning on intrinsic interest and enjoyment (Norman & Schmidt 1992 and Albanese & Mitchell 1993). From my own experience I believe that there is truth to the claim of the development of a team spirit or camaraderie between students of the same group and its positive effects.

3.3.6.4 Problem-based learning problems

Referencing Barrows overview paper again (Barrows 1996 p.6) he explains the role of the problem in the problem-based learning pedagogy “It represents the challenge students will face in practice and provides the relevance and motivation for learning. In attempting to understand the problem, students realise what they will need to learn from the basic sciences” and goes on to say “the curricular linchpin in PBL-the thing that holds it together and keeps it on track-is the collection of problems in any given course or curriculum with each problem designed to stimulate student learning in areas relevant to the curriculum.”

Gijsaelaers (1996) points to some ineffective design issues for problems:

- Questions that are substituted for student generated learning issue
- Title of ineffective problem is similar to titles of textbook chapters
- An ineffective problem does not result in motivation for self study

Wilkerson & Gijsaelaers (1996) describe the problems as different from the calculations or recitation questions found at the end of a textbook chapter. Instead the questions are complex, ill structured, multidisciplinary, and meaningful. The use of the term ill structured is a misnomer as the problems are well structured so that there are no clear set of rules or methodology that will result in a solution. The problems engage students in problem solving behaviours relevant to the discipline under study. The authors in turn describe four principles for effective problems:

- The manner in which the problem is encountered by the learners is dependent on the objective to be accomplished (for example: if you wish the students to develop the ability to make assumptions to solve problems then a problem must have the need to make assumptions in it.
- Problems should be provocative, compelling and controversial
- Problems should be ill structured that is that there should be no clear set or rules or methodology that will result in a solution.

- Problems should be relatable to problems professionals encounter on a regular basis.

Dolmans *et al.* (1993 p.209) talk about one of the basic tenets of curriculum design when it comes to a problem-based learning course and argue that:

> *"the goal of curriculum design in this area should be to construct problems that are indeed effective in reaching the intended learning outcomes. Whether students undertake learning activities planned by the faculty members is to a large extent determined by the learning issues generated. If students fail to generate the appropriate learning issues, the preset objectives are not identified, and hence the intended learning outcomes are not accomplished"*.

The matching of learning issues with faculty learning outcomes has been the focus of much research in problem-based learning (Coulson & Osbourne 1984, Shahabudin 1987 and Tans *et al.* 1986), with a variety of different methods used. Dolmans *et al* (1993 p.209) conclude their paper with the view that "students in a problem-based learning curriculum are able to determine what they need to know and what is relevant to learn".

3.3.7 Problem-based learning in DIT

As mentioned in the introduction section, which gave a synopsis of events and reasoning behind the introduction of problem-based learning in DIT, the pedagogical model was chosen to address several problems encountered within the context of the Irish educational system. Part of the reasoning behind this pedagogical choice was that problem-based learning would encourage students to adopt a deep approach to their learning, for them to take more control of their learning and that the approach would support the development of students' conceptual understanding and problem solving skills. The particular mode that the DIT School of Physics problem-based model took, as defined by Savin-Baden (2005), is an amalgamation of mode 1 "the single module approach" and mode 5 "tutors see PBL as a vital component of the curriculum". This is because the physics module is more extensive than a single module as it is a vital component of the curriculum. It is worth noting that although problem-based learning is the main teaching method for the physics course, a section is delivered through peer-instruction (Mazur 1997) and there are also traditional tutorials integrated into the design to allow for learning through cognitive apprenticeship and repetitive exercises. Although cognitive apprenticeship is not typically associated with the problem-based learning model, it was thought to be important to integrate these elements into the course (Bowe & Cowan 2004).

The first year physics syllabus is covered by approximately 30 problems (see Appendix B for example) which are "real", engaging, place the group in a "professional" role, require the students to make assumption, approximations, and deal with omitted information (Bowe & Cowan 2004). In the following section a description of a typical problem-based learning week in the DIT model of problem-based learning is provided.

All the problem-based learning physics problems are put online immediately before the students encounter them in class. The students bring in a print out of the problem and one student normally reads it out aloud to their group. A discussion occurs in which the students attempt to discover the underlying process or principles of the problem. They use a system called the 'four columns'. The four columns is a method where students place four sheets of A3 paper on the walls of the class with the following headings: Ideas, Facts, Learning Issues and Actions. The students attempt to fill these columns with information they can obtain from the problem itself or through prior knowledge. After the students complete the four columns they would usually try to generate a plan and discover what issues need more study. These issues become the learning issues and are assigned to individual students or the group as a whole. The first session ends and the students go prepare for the next session using additional resources to study the issues they have been assigned. In the second session, students' return to the group process and discuss findings and difficulties with their fellow students in the tutorial group and formulate a method to solve the problem and obtain a clear understanding of the underlying physics concepts of the problem. The problem-based learning groups are guided by the tutors in both sessions and the tutors examine students understanding of the physics concepts contained within the problem.

Assessment has an important role in driving learning in any course design and the assessment strategy in a problem-based learning course has to help students develop as learners and as individuals within a group. As previously referred to, assessment has a role in influencing the approaches to learning adopted by a student in a course. One of the key research questions of this thesis is what approaches to learning do students have within the context of problem-based learning. In order to answer this question, it is important to outline the assessment strategy of the problem-based learning course in question. The DIT design team of the problem-based learning course state in Bowe's chapter (Bowe 2005) on assessing problem-based learning, that they were aware that the previous design of summative tests, laboratory practice and examinations at the end of the academic year were encouraging surface and strategic approaches to learning and that they wished to move away from this: "it was envisaged the problem-based learning approach would encourage students to adopt a deep approach to learning" (Bowe 2005 p.103) and it was designed so that it would be constructively aligned with the learning outcomes as confirmed by Cowan (Bowe & Cowan 2004). It was important that the assessment strategy also required students to take this approach.

The DIT design team also stated that the assessment strategy aimed to:

- Examine conceptual understanding and problem solving skills
- Encourage and reward individual contribution to the group process
- Support and evaluate the development of group, communication and presentation skills
- Identify problem and areas of potential improvement
- Monitor progress

Focusing on the above aims, it is important to focus on how the individual contribution to the group process was assessed, as this assessment practice may have had a significant impact on how students behaved in a problem-based learning session and from session to session which is one of the main research questions for this thesis. From the same paper Bowe outlines the reasoning behind the individual assessment and this particular aspect of the assessment strategy

> *"A greater challenge arose from the aspiration to assess individual contribution to the group process. It was felt that the assessment strategy should reward those students who work hard in the group process and endeavour to contribute constructively to the process. In this way the strategy should also penalise those students who do not make an effort to contribute to the group process. For the purpose of formative assessment, it was felt that the feedback should be individualised to help each learner and this required assessing each student's contribution to both the process and the products. To overcome some of the problems associated with assessing individual contribution to both the process and the product, it was necessary to involve the students in the assessment process through the use of self and peer assessment."(p.105)*

Self and peer assessment is a critical element of this course design as it encourages students to become self directed learners which is one of the theoretical underpinnings of a problem-based learning course design and it encourages students to develop meta-cognitive skills. However, the self and peer assessment element of the course is not implemented until the second semester of the course, after the students have been assessed and given feedback by the tutors for the first semester. This research study is based primarily in the first semester. It should be noted that the rationale for each assessment method, along with the criteria, are discussed with the students in the induction process as well as at various intervals throughout the academic year and a copy of the assessment of contribution to the group process table can be found in Appendix D. Initially, there were two separate assessment tables one for the group process and then an individual one for the chair of the group. However, as discussed above, the chair element of the course design had been removed and so the assessment for the chair has not been included in this thesis. The assessment for the continuous assessment mark was broken down into two areas. 85% of the mark for continuous assessment was calculated from the mark out of 10 that the students were given after every problem. The remaining 15% is taken from the students results on their written reports that the students completed after every problem.

3.3.8 Previous methods of group analysis in physics

Although research into co-operative learning has occurred in the field of physics education (Heller *et al.* 1992a, 1992b) it has been predominantly focused on how to start teaching using co-operative learning or the results of teaching by co-operative learning methods. There has not been much research on what actually occurs in these environments and how conceptual understanding is constructed within these groups. Rachel Scherr (Scherr 2008) has being researching gesture analysis in small tutorial groups and investigating how students' gestures fill in gaps in student verbalisation. That study also gave insight into student ideas and their construction of their ideas which has just been recently published. The Scherr study had been ongoing for a number of years and inspired research by Conlin *et al.* (2007) in which they investigated the dynamics of students' behaviours and reasoning during collaborative physics tutorial sessions.

Using video-taped footage of students working off a problem work sheet, they coded students' behaviour with behaviour modes or "frames" with four frames in total: Discussion, Worksheet, Socialising and Receptive to Teaching Assistant. Discussion is described as sitting up, eye contact with peers, subdued gestures and a lower vocal register. Worksheet is described as hunched over, eyes on worksheet, low vocal register and writing. Socialising is described as fidgeting, laughing, looking away and touching face/hair. While receptive to teaching assistant is sitting up, eyes on teaching assistant, subdued gestures and lower vocal register. These behaviour codes were then correlated with the amount of time group members stayed in a behaviour mode and the amount of mechanistic reasoning carried out in that mode. Mechanistic reasoning in the Conlin study is described as an argument that lays out the casual mechanisms by which the phenomenon occurs given the laws and initial conditions. The study had a set amount of conditions that must be met in order for mechanistic reasoning to occur. It was found that animated discussion had the most amount of mechanistic reasoning occurring within this code. Their research relates to my own in a number of ways. Its aim of investigating the dynamics of student behaviour is similar to my own but it based on a very different context. The research method of observation is also similar and has informed this study.

However, the participation (behaviour) examined in my study is completely different than the mechanistic reasoning which the Conlins study is examining. The goal of Conlin's research is to understand the substance of their reasoning. Where my study is trying to investigate the level and type of participation students have in problem-based learning, why students participate in this way and what effect this participation has on the learning.

3.4 Physics Education

3.4.1 Introduction

Arnold B. Arons was one of the first physics educators to report the effectiveness of his teaching within a physics class (Arons 1965, 1976, 1997). Along with other physics educators (Karplus 1977) he began to realise that physics instruction was no longer about the reproduction of students in their own self image or in other words physicists producing more physicists (Redish 1994). This realisation came about due to the change in student profile attending their classes. Historically, the students who studied physics were highly motivated and interested in the subject and so would become the next physicists. However, as the landscape of higher education began to change (Woodard *et al.* 2000) and became more accessible to all, traditional, highly motivated students were replaced in physics classes with students who viewed physics merely as a compulsory element of their course.

Even with these early instigators of physics education research, physics education itself remained relatively unchanged for over fifty years (Knight 2002; Redish 2003). It is only in the past few decades that there has been a veritable explosion in the amount of research in physics education. Evidence of said explosion can be seen in development of a journal dedicated to physics education research in American Physical Society (APS): Physical Review Special Topics (PRST) – Physics Education Research (PER) and the research published within it (Finkelstein & Pollock 2005; Rimoldini & Singh 2005; Kohl & Finkelstein 2005; Bao & Redish 2006; Ding *et al.* 2006; Scott *et al.* 2006; Tuminaro & Redish 2007; Yerushalmi *et al.* 2007; Pollock *et al.* 2007; Scherr 2008; Kohl & Finkelstein 2008; Thornton *et al.* 2009; Brookes & Etkina 2009). The above listed papers are evidence of the vast array of ongoing studies in physics education research such as attitude evaluations/epistemological beliefs (Adams *et al.* 2006; Redish *et al.* 1998), student conceptions/cognitive processing (Aguirre 1988; Trowbridge & McDermott 1980, 1981), expert/novice studies (Stocklmayer & Treagust 1996; Larkin & Reif 1979) and curriculum development (Reif *et al.* 1976; Heller *et al.* 1992). Below I provide an overview of the relevant and pertinent research that has informed this research study.

Like many other disciplines, physics has tended to be governed by the use of pedagogical approaches associated with behaviourist learning theory (Skinner 1968) as explained in section 2.2.2. That is, the approaches have been biased towards teacher centred approaches which try to transmit the 'correct' information to the students (Redish 2003) or as Arons puts it (Arons 1997 p.1) "teaching of physics is governed by a long-established tradition of 'backwards science', where physics is presented as a collection of end products, formulae, well-formulated definitions, canonical statements about atoms and electrons, quarks, gluons, big bangs, black holes and other 'esoteric vocabularies of modern physics'". At present, and in the past, the presentation of such knowledge to students has been dominated by passive student lectures, recipe laboratories, and algorithmic-problem examinations with no interest in the cognitive mechanism that may be used by an individual to learn a process, nor is there an interest in whether the process learned made any sense to the individual and hence if they could use that knowledge in a different context.

However, physics education research has developed rapidly over the past forty years and the shortcomings revealed by much of this research have become more apparent with the changes in student profile as mentioned above, due to things such as mass education, diversity, competition and information technology (McDermott 1991). A possible explanation for these shortcomings may be that traditional physics education tends to rely on the assumption that systematically and repetitively solving relatively simple algorithmic problems will develop in students an understanding of the physics concepts and principles, as well as an appreciation of the role they play in solving problems (McDermott 1991; Leonard *et al.* 1996; Mazur 1992). To see evidence of this, one merely has to turn to one of the many physics text books available and examine how this is presented (Young 1999; Wilson & Buffa 2002).

Arons (1997 p.1) is particularly critical of this type of teaching and states “We compose detailed instructions for straightforward solution of end-of-chapter problems and for easy arrival at correct results in the laboratory exercises. We do our best to equip our students with correct answers, to save them from the trouble of thinking, and to ensure examination success”. He continues “We are merely 'cultivating blind memorisation without comprehension' and are 'crushing our students into the flatness of equation-grinding automats. We do not even give them a chance to begin to understand what "understanding" means”. A great deal of the research that has been done in the last forty years has gone some way towards demonstrating that problem solving by itself does not develop a deep understanding of concepts and principles. Students participating and learning through this type of activity often become proficient problem solvers, gaining the ability to solve problems by equation recognition alone (Clement,1982; McDermott 1984, 1991; Hestenes *et al.* 1992; Bowden *et al.* 1992). In Bowden’s research, in particular, it was found that “The capacity to get the correct numerical solution has a low correlation with the capacity to demonstrate qualitative understanding of the concepts in different circumstances” (Bowden 1992 p. 267). Other studies have shown that students, who could easily solve standard textbook problems, were often unable to relate the results to other, more complex situations (Trowbridge & McDermott 1981; McDermott *et al.* 1987; Ambrose *et al.* 1999).

The previously dominant learning theory of behaviourism provides another significant concern in its approach to physics teaching in that its proponents have a propensity to view students as ‘blank slates’. Information is transmitted or given to the students from the teacher and in order for a student to develop a deep conceptual understanding of the material they must repetitively solve problems. However, results from physics education and cognitive research show that students begin a physics course with their own conceptual framework developed either through their own experiences (including formal instruction) or through ‘common sense’ (for example see: Halloun & Hestenes, 1985a, 1985b; Redish *et al.* 1998; Redish 2003). Students who enter a classroom have generally been constructing knowledge for some years and by the time these students reach third level education they could have constructed twenty years of knowledge from their previous experiences of the world and learning physics. This view of learning at this stage of the thesis may be regarded as constructivism which has been previously described in more detail in section 2.2.4. Constructivism has become the dominant paradigm in modern educational theories in the United States.

The shift of dominance from behaviourism to constructivism resulted in the requirement to change from teacher centred approaches to instruction to student-centred approaches to learning (Rogers 1983). The emphasis in a student-centred approach is on the student and specifically what the student is learning (not on what the teacher is covering or transmitting), what the student knows when they begin and how they interact with the learning environment and content (Redish 1994). In a student-centred learning environment the principle role of the lecturer has changed from transmitting information to establishing and supporting learning environments which enable the student to challenge and test their world views.

3.4.2 Students' conceptual difficulties

As mentioned previously, the quantity of physics education research studies has increased significantly in the last forty years and the focus of much of this research has been to investigate the difficulties students have with the conceptual nature of physics. Although a lot of the research described is not directly linked to this research project, the following review does, however, give a succinct background to the history of the studies related to students' understanding in mechanics which of the contexts in which this research study is based. It also maps the development of diagnostic tests, specifically the Force Concept Inventory (FCI) and the Force and Motion Conceptual Evaluation (FMCE) (the FMCE being used in this project as one of the gauges of students development). It also plots the evolution of physics education towards the use of a phenomenographic methodology in describing variations in students understanding of mechanics. This again does not relate specifically to this research project, as I am not investigating the variations in students conceptual understanding but the variations in students approaches to their learning in the context of a first year problem-based physics course. I do think it is important to outline research studies which have used similar methodologies in similar contexts to reinforce the applicability of the methodology within this research project.

3.4.2.1 Investigations of Misconceptions

The Physics Education Group in the University of Washington (PEG in UW) take a constructivist approach to student learning, believing that "all individuals construct their own concepts, and the knowledge they already have…significantly affects what they learn" (McDermott 1991 p. 305). Throughout the first decade of their research, attention was mainly focused on student difficulties in mechanics. Two in-depth studies investigating student understanding in kinematics (Trowbridge & McDermott 1980, 1981) examined the ability of a range of students from different academic backgrounds (e.g. non-calculus and calculus physics students, lecture based and self-paced courses) to apply the concepts of velocity and acceleration in interpreting simple motion of real objects. The aim was to identify specific problems in kinematics and gain insight into possible kinematical origins of difficulties with dynamics. The method of investigation for each of these was the 'individual demonstration interview', and the measure of understanding of a kinematical concept was "the degree to which an individual successfully applies that concept to the interpretation of simple motions of real objects" (Trowbridge & McDermott 1981 p. 242).

The first test was the 'Speed Comparison Tasks' (Trowbridge & McDermott 1980), where students were presented with demonstrations of two motions and were asked to identify if and when the speeds of two balls were the same. It was clear from the student responses that the students where confusing speed and position. Most of the students interviewed before instruction were subsequently interviewed after instruction. However, the researchers deliberately administered only pre-instruction interviews to one group and only post instruction interviews to another group. Out of all the students interviewed on both occasions about one-fifth still confused the concepts of speed and position on post instruction interviews.

The second of these two studies used acceleration comparison tasks (Trowbridge & McDermott 1981). Again, the students were asked to observe and compare the motion of two balls having different accelerations. The students were encouraged to concentrate on the main conceptual issues rather than on subsidiary experimental details and were permitted to view the demonstration many times. Success on this task meant that the student used a valid procedure containing a conceptual explanation for comparing accelerations as opposed to the non conceptual method of substituting into a kinematical formula. The researchers found that students used a number of procedures to compare the accelerations, with only two of the procedures showing a qualitative understanding of acceleration as the ratio between the changes in velocity to the change in time. Again the group interviewed the same students before and after instruction. Of all the students interviewed about one third still confused the concepts of velocity and acceleration on post-course interviews and in the introductory level populations studied, about two-thirds of the students did not use ratios to compare accelerations in post course interviews. One conclusion that the researchers drew from these two studies was that "active intervention is necessary for overcoming confusion between related but different concepts" (Trowbridge & McDermott 1981 p. 253).

The group then used the results from the above research on student understanding to guide the development of a conceptual approach to teaching kinematics (Rosenquist & McDermott 1987). The group found that instruction based on observation of actual motion could help students develop a qualitative understanding of velocity and acceleration and to distinguish concepts of position, velocity and changes in velocity and acceleration from one another. At the same time, the group carried out a study investigating student understanding of the concepts of impulse and work and the relationship of these concepts to changes in momentum and kinetic energy (Lawson & McDermott 1987). Again, in this mainly descriptive study the method of research was the 'individual demonstration interview'. Overall, the researchers found that many students "experienced considerable difficulty in a straight forward application of the impulse-momentum and work-energy theorems to the actual one-dimensional motion of an object under constant force" (Lawson & McDermott 1987 p. 816). From all of the above mentioned studies, the general conclusion was made that “fundamentally important features of concepts that are not easily visualised will be missed if they are present verbally, whether by textbook or lecture” (Lawson & McDermott 1987 p.817). This group then used the same methods to investigate students’ misconceptions of light (Wosilait *et al.* 1998; Ambrose *et al*. 1999; Heron & McDermott 1998 and Vokos *et al.* 2000). The group also then branched out into thermodynamics and pressure (Loverude *et al*. 2002). Another group that has completed similar research into misconceptions is the Super Physics Education Research Group (Muller *et al.* 2008 and Muller *et al.* 2007) based in Sydney University.

3.4.2.2 Studies concerning conceptual knowledge in mechanics

Many studies all over the world have been conducted investigating student learning difficulties in the past forty years. They either involved investigating students’ preconceptions or students misconceptions (to name but a few, Aguirre & Erickson 1984 in Canada; Finegold & Gorsky 1991 in Israel; Gunstone & White 1981; Gunstone 1987 in Australia; Caramazza *et al.* 1981; Clement 1982; Peters 1982; Halloun & Hestenes 1985a; Hestenes & Halloun 1995 in the US; Viennot 1979; Saltiel & Malgrange 1980; Watts 1983 in Europe). The results of these studies were a taxonomy of students’ difficulties in kinematics and dynamics. John Clement (1982) introduced the preconception “motion implies force” concept to which he attributed three main characteristics; continuing motion implies a force, one force overcomes another and forces ‘die out’ or ‘build up’ (although this preconception had been observed in previous studies for example see Champagne *et al.* 1980). However, these characteristics of the stable preconception have since been labeled phenomenological primitives (diSessa 1993) and context dependent facets (Minstrell 1992). Aguirre and Erickson (1984) (and subsequently Aguirre (1988) and Aguirre & Rankin (1989)) found that students had stable alternative conceptions of vector kinematics and that up to 50 % of these students maintained these naïve conceptions after formal instruction in mechanics.

A study carried out in 2003 (Nguyen & Meltzer, 2003) confirmed that students retained conceptual difficulties with vectors after formal instruction in the area. For other studies involving student difficulties and understanding of vector concepts see Knight (2002); Flores *et al.* (2004) and Shaffer & McDermott, (2005). Halloun & Hestenes (1985a) produced results which suggested that students had a number of 'common sense concepts' regarding motion both prior to and after formal instruction. While there are still numerous studies being carried out investigating student difficulties in mechanics (for example see Rimoldini & Singh 2005; Poon 2006 and Sharma & Sharma 2007) much research within the physics education research community has now shifted from exploring these stable alternative conceptions to finer grained 'primitives' or 'resources' as described above (for example see: Hammer 2000; Bao *et al.* 2002 and Smith & Wittmann 2007) and many recent studies focus on the cognitive constructs of student thinking and learning (for example see: Bao & Redish 2006; Wittmann 2006 and Podolefsky & Finkelstein 2007).

There have also been numerous studies carried out which do not specifically focus on the difficulties that students have in understanding the conceptual nature of mechanics but rather aim to describe the various ways in which these students understand these concepts (for example see: Dall'Alba *et al.* 1989; Johansson *et al.* 1985; Millar *et al.* 1989; Prosser & Millar 1989; Bowden *et al.* 1992; Dall'Alba *et al.* 1993; Ramsden *et al.* 1993; Walsh *et al.* 1993 and Sharma *et al.* 2004). These studies produce sets of hierarchical categories which describe the variations in the ways in which students experience the concepts in question and through the hierarchical nature of the categories developments in teaching and assessment practices may be made in order to move students from lower levels of understanding to higher levels. For example my colleague Laura Walsh (Walsh 2008 and Walsh *et al.* 2006, 2007 and 2009) investigated, as part of a bigger study into students approaches to problem solving, first year introductory college students' conceptions of acceleration. Walsh constituted six different categories of description for students' conceptions of acceleration.

As part of a large-scale research project, researchers from Australia, UK and Sweden collaborated to produce phenomenographic categories describing the variations in students' understanding of mechanics. A number of students were invited to participate in individual interviews in which they were asked to respond to a number of questions. An important point about these interviews was that students were encouraged to give full explanations of their understanding. Bowden *et al.* (1992) constituted categories describing the variations in understanding of displacement, velocity and frames of reference by analysing the data obtained from interviews with students. Ramsden *et al.* (1993) report from analysis of the same set of interviews categories which describe the variations in students' understanding of speed, distance and time. Walsh *et al.* (1993) reported on the variations in understanding of relative speed and Dall'Alba *et al.* (1993) produced six categories which described the qualitatively different ways in which the students understood acceleration and compared these to textbook treatments of acceleration.

3.4.3 Development of research based diagnostic tools

In the early 1980's staff in the Department of Physics in Arizona State University (namely Ibrahim Halloun and David Hestenes) became aware that conventional instruction was not taking into account the fact that students enter third level with their own 'common sense' concepts of motion (Halloun & Hestenes 1985b). They were aware of current research in the area of physics education and found that it had, up to that time, mainly focused on isolated concepts. Therefore, they formed the Physics Education Research and Development group with the aim of designing and making an instrument for assessing the knowledge state of students beginning to study physics, which would include mathematical knowledge as well as beliefs about physical phenomena (Halloun & Hestenes 1985a).

The Physics Education Research and Development group in Arizona State University designed two tests, a physics diagnostic test and a mathematical diagnostic test to assess the knowledge state of a student entering into an introductory physics course. The physics diagnostic test would be used to assess the students' qualitative conceptions of common physical phenomena in both pre and post test form and the mathematical diagnostic test would be used as a pre test to assess the students' mathematical skills. The questions in the physics diagnostic test were chosen to highlight the difference between common sense and Newtonian concepts (the term common sense here refers to that of an individual with little formal instruction in physics, relying only on personal experience) and to identify misconceptions that had been discovered by previous researchers.

The test was administered in various forms to over one thousand college students in introductory physics courses, initially requiring written answers. The most common answers were then collated to form multiple choice questions, which made the finished product, the physics diagnostic test, easier to grade. Extensive measures were taken by the group to validate and examine the reliability of the test. For instance, the tests were given to professors, graduate students and introductory physics students to ensure that they all understood the questions and optional answers. Interviews with a sample set of students were also used to establish the reliability of the tests. The group found that almost all students gave the same answers in the interviews as in the written test and, moreover, they were not easily swayed from their answers when questioned, which implied that the answers reflected stable beliefs. The group concluded that “a student’s score on the diagnostic test is a measure of his qualitative understanding of mechanics” (Halloun & Hestenes 1985a p.1048). The other test developed was the mathematics diagnostic test which was constructed in much the same way with the group noting that incorrect answers were not random but indicated common misconceptions and that these errors could tell something about the way that students think.

Both tests were administered initially to eight groups of students from different backgrounds, each with a different instructor. From correlating scores on the mathematics and physics pre tests with course performance, the researchers came to the conclusion that the “test results show that a student’s initial knowledge has a large effect on performance in physics but that conventional instruction produces comparatively small improvements in his basic knowledge” (Halloun & Hestenes 1985a p.1048). This group of researchers later used the information obtained from the mathematics and physics diagnostic tests to further refine these tests into more valuable resources, namely ‘The Force Concept Inventory’ (FCI) (Hestenes *et al.* 1992) and ‘The Mechanics Baseline Test’ (Hestenes & Wells 1992).

The FCI probes the students' common sense beliefs on force and examines how those beliefs compare to Newtonian mechanics. The researchers have broken down the concept of Newtonian force into six dimensions, where all six are required for the complete concept. The group suggest that errors on the test are actually more informative than correct answers, as they bring to light a students' misunderstanding of a particular concept. Again, they feel this test can be used for multiple purposes: as a diagnostic tool, as a placement examination or as a tool for evaluating the effectiveness of instruction.

3.4.3.1 Force Motion Conceptual Evaluation (FMCE)

Another research-based multiple choice assessment of student conceptual understanding is the Force Motion Conceptual Evaluation (FMCE) developed by Ron Thronton (Tufts University) and David Sokoloff (University of Oregon) in 1998 (Thornton & Sokoloff 1998). Although the inventory is similar to the FCI described above, it appears to be more statistically sound, as it uses a number of questions on each concept to cross-reference the students' understanding. The FMCE was developed in much the same way as the FCI, using results from physics education research (Thornton & Sokoloff 1998) and was carried out pre and post instruction on a large number of students. As the researchers point out, some of the multiple choice questions on the inventory serve specific purposes, such as identifying students who are beginning to accept a Newtonian view and those far from consistently adopting a Newtonian view. Using open ended, alternative questions, the researchers were successful in validating the FMCE to a very high degree (Thornton & Sokoloff 1998 p. 345):

> *The agreement between the multiple choice and open answer responses is almost 100%. Such results give us in confidence in the significance of student choices.*

The researchers point out there are very few random answers on the test and with even the less common beliefs about motion being represented in the distracters (wrong answers), students almost always find an answer they are satisfied with. The FMCE is included in Appendix E.

3.4.3.2 FCI or FMCE as gauge of quality of learning

There has been some debate as to the validity of both the FMCE and the FCI as tools to evaluate students learning in the mechanics sections of an introductory physics course. The section below discusses some of more salient points of the debate and explains why it is valid to use the FMCE in this research study based on the arguments put forward and the goals of the course that is being studied.

Hake’s research, such as that on normalised gain (Hake 1998) and his use of the above conceptual evaluations as tools to evaluate the difference between ‘Interactive Engagement’ courses (Hake 1998) and traditional courses, has come under attack for numerous reasons (Hake 2002; Nuhfer 2006). Hake (2002) discusses the criticisms of his research in this paper. For example, his definition of the difference between an interactive engagement course and traditional taught courses (Hake 2002) has been criticised for the broadness of classification of interactive engagement courses.

More recently a message board (AERA Division L: Educational Policy and Politics Forum 2008) response to another of Hake’s articles “pre-to-post tests as measures of learning/teaching” (Hake 2008) by Logan McCarthy (McCarthy 2008) argues on the validity of a number of points made by Hake in the past. McCarthy argues that the highest form of learning that we achieve in introductory courses are “skills” and not facts or concepts, thereby discrediting the use of conceptual tests as important gauges of learning. He also makes the point that pre/post testing inevitably promotes "teaching to the test" and so makes the results of such tests invalid. Ed Nuhfer also states that “there are people who proclaim multiple choice tests to be the standard for determining quality of education, but I know of no one outside politics who's stupid enough to make such an absurd proclamation” (Nuhfer 2008). The last statement is important to this research study as this study uses the FMCE as a gauge of students’ learning and posits that gain in conceptual knowledge is one of the key learning goals for a student studying first year physics. Gain in conceptual knowledge is one of the key, learning goals of the problem-based learning course but this study does not base all of the learning gained by students primarily on the FMCE but instead includes the continuous assessment marks for problem-based learning sessions and end of semester exams.

Hake's response to Nuhfer is that these tests only measure the minimal conceptual knowledge of mechanics and that there are many other desirable outcomes from a first year physics course and then proceeds to list them. Again Hake's reply to McCarthy's statement is that conceptual gains are not the sole focus of physics courses and lists several physics courses and their goals. For McCarthy's second reservation Hake queries McCarthy's wondering of 'teaching for the test' as he argues that instructors using these assessments for the purpose of promoting the improvement of classroom teaching and learning and not to comparatively rate themselves, their students or institutions. For this study it is appropriate to use the FMCE as a gauge of one important aspect of student learning even though it is not the only outcome of a students' first year experience that would be viewed as positive. Clearly communication skills, ability to work in groups, to formulate understanding and convey understanding and ability to solve real world problems are all important outcomes for a first year course but not quantifiable by an examination and will be instead investigated by interviewing the students taking part in the study.

3.5 Chapter Summary

This chapter discussed the other areas of literature that influence this research study with the following prevalent areas discussed:

- That there are different conceptions of learning and understanding and within these conceptions are levels of sophistication.

- Conceptions of understanding can be dependent on subject.

- The chapter outlined the underlying constructivist theory of problem-based learning.

- The chapter indicated the crucial elements of a problem-based learning course and that they are designed to result in a learning environment that encourages deep learning. The research referring to these elements (assessment, problem design, tutors...) was also discussed to further indicate the effects these elements have on the learning environment.

- Outlined the criticisms of problem-based learning as a way of teaching and presented rebuttal arguments for each criticism.

- Described the DIT problem-based learning environment and the reasoning behind the elements that make up the design.

- Demonstrated previous methods of analysing behaviour in problem-based learning environments.

- Outlined students conceptual difficulties in physics and the development of conceptual inventories to assess conceptual understanding.

CHAPTER 4

RESEARCH DESIGN

4.1 Introduction

Chapters 2 and 3 reviewed the key literature and research studies that are pertinent to the study of students' approaches to learning. This chapter is concerned with how these issues might be investigated empirically in the context of my study. What follows is a presentation of my views on knowledge and learning through both a discussion of my views and the presentation of previous literature that has shaped and aligned my views. To remind the reader of the main research goals of this study here are the research questions again:

- What are the variations in students' approaches to their learning and variations in perceptions of a physics problem-based learning environment. What is the relationship between perception and approach?

- How do students manifest their approaches through their actions in problem-based learning sessions?

- What is the relationship between students approach, perception and their learning outcomes?

Considering the scope of the questions, the research has had to be undertaken within the appropriate framework, in order to answer the research questions and that framework is education research.

Many different frameworks for designing education research have been presented in past literature (Anderson 1998; Crotty 1998 and Creswell 2003). For example, Creswell (2003) discusses the use of three framework elements: knowledge claims, strategies of inquiry, and methods. Whereas Crotty (1998) outlines a four level framework comprised of: epistemology, theory, methodology and methods. Both frameworks are equally valid and in the initial stages of my research I based my approach on Crotty's framework as it gave a more recognisable structured step by step approach which I was more comfortable with due to my background in science. As I became more comfortable with educational research I felt comfortable stepping away from the more structured approach and instead I employed Creswell's approach for this thesis.

This chapter begins with a discussion of the assumptions with which I began this research, including the theoretical perspective within which the research is grounded. The capability to reliably answer the research questions in a study such as this is deeply embedded in the strategy of inquiry which is employed. As the main strategy of inquiry, or as I have referred to it a methodology, a phenomenographic approach was chosen. It is the most appropriate with which to answer my research questions and this choice will be fully justified in section 4.4 of this chapter. Section 4.5 describes in detail the methods of data collection and analysis which were employed in this research and the final sections in the chapter describe the participants who took part in the study and a discussion of the ethical considerations. This chapter is a necessary prelude to the remainder of the thesis as it places the research data, analysis and participants within the context of the study.

4.2 Theoretical Perspective

Given that I have already referred to approaches to learning and the effect environment, context and past experiences have on these approaches to learning, it would be fair to say that the reasoning behind my initial choice of research methods was based in large part on my unwillingness to completely adopt the qualitative methods typically associated with educational research and a reticence to let go of the methods informed by my scientific background. When choosing the research methods, I focused my attention on the research questions and, hence, allowed myself the choice of both qualitative and quantitative methods. However, after examining relevant literature, I became very much aware of the fact that the research questions were very much informed by my own epistemological stance and the theoretical perspective from which I set out to address the research project. As Lincoln and Guba put it (Lincoln & Guba 1994 p.105) ‘questions of method are secondary to questions of paradigms’. The fact that the research questions concentrate not on “fact” but on experiences, conceptions and perceptions lie in my epistemological stance which evolved from the literature review and the assumptions, that I brought to this research.

One of the assumptions that I brought to this research is that reality is neither external nor internal. Instead, it is a relation between the two and, therefore, knowledge is not entirely constructed internally nor does it exist without being conceptualised. Therefore my theoretical perspective is a relational perspective. There is now over 30 years of research data of students' and teachers' experiences of university and college science education from a relational perspective beginning with Marton’s work about approaches to learning which has been discussed in some detail in the previous chapter. He and many researchers believe that learning and, therefore, knowledge is not discovered but constituted through an internal relationship between the individual and the world (Marton 1981, 1986). There are two different research perspectives in student learning: the observational and the experiential. Van Rossum & Schenck (1984) and Trigwell *et al.* (1994) call the two perspectives a first order approach and a second order approach.

A first order approach emphasises describing various aspects of reality of teaching and learning situations. Research into student learning that takes this perspective focuses on the learner (the learners characteristics, the learners study skills) as well as certain aspects of the learner’s environment (departmental characteristics, the demands of the learning task) and it is from the perspective of an independent observer or researcher. The second order perspective is taken by researchers who concentrate on how the learner perceives reality; it is the experiential perspective described by Marton & Svensson (1979). In terms of higher education then, the second order perspective looks at how students perceive their academic environments, the demands of their courses and their own learning approaches. You cannot observe how a student approaches their learning in an environment because approach encompasses students intention and strategy. So to explore participants’ conceptions of approaching their learning in the context of problem-based learning, the answer cannot be derived from what we know and what people write about approaches to learning but we must focus on what people conceive, perceive and experience in approaching their learning in this context.

So, using a second order perspective, I have explored students' experiences of approaching and perceiving their learning environment. The term experience is used here not as involvement in or knowledge of their approaches to the learning environment but in a much broader sense of how students are aware of their approaches to the learning environment. It follows then that this research is my interpretation of students' experience of physics taught through problem-based learning with the intention that I would achieve a better understanding of the variations in these students' approaches to learning and perceptions of the problem-based learning environment.

4.3 Theoretical Assumptions

In Chapter 2, I discussed constructivism as a learning theory and also as the underlying theory behind problem-based learning. Section 2.2 concluded though with a non dualistic view of how students learn, with learning being constructed through prior experiences, perceptions and approaches rather than discovered (Prosser & Trigwell 1999). My theoretical perspective (i.e. my underlying assumptions about the nature of learning) can be described as constitutionalism. This perspective colours both my views on the nature of learning and of how to investigate students approach to their learning. The review begins with a discussion of constructivism which then leads on to constitutionalism. The section ends with an exploration of how students experience and the theory of variation and awareness.

4.3.1 Constructivist epistemology

The idea of constructivism was developed by merging various cognitive approaches with a focus on viewing knowledge as being constructed rather than being discovered (Marton & Saljo 1976a). According to the constructivist paradigm, knowledge is internally constructed by the learner and involves making meaning of experiences. Since the construction builds recursively on the knowledge the student already has, each student will construct an individual version of the knowledge.

Constructivists do not assume that reality or truth exists and can be understood, instead they assume that knowledge or reality is constructed by the researcher and is likely to change. From an individual perspective, knowledge is constructed internally and tested through interaction with the outside world (Von Glaserfeld 1995). Knowledge is no more or no less the sum of constraints that it can be held to through its testing on the outside world. It is this relationship with the external world and the fact that constructivists assert that the individual and the world are separated from each other that results in the main criticism of constructivism and the alternative theory of constitutionalism. The difference between the two theories is that constructivism is based on dualistic assumptions and constitutionalism is based on non dualistic assumptions.

Dualistic assumptions refer to a belief that knowledge is a fixed entity, separated from other pieces of information, including the learner. According to non-dualistic assumptions, knowledge represents ways of experiencing the world and is instead constituted through an internal relationship between the knower and the knowledge. With regards to learning, non dualistic assumptions imply that learning is about integrating new knowledge with prior knowledge to construct meaningful understanding (Marton & Booth 1997). It follows that from a non-dualistic perspective, if the learner has come to experience a phenomenon in a more complex and meaningful way, a change is implied and learning has taken place. A great deal of non-dualistic research comes in the form of phenomenography. As mentioned previously Marton & Saljo (1976a, 1976b) described qualitatively different ways of approaching ones learning, whereas Perry (1988) identified qualitatively different conceptions of knowledge. Marton & Booth (1997) and Ramsden (1992) maintain that learning entails a phenomenon being experienced in a complex way. These non-dualistic assumptions are the key difference between constructivism and constitutionalism or as Marton & Neuman (1989) put it:

> *"There is a dualistic assumption underlying constructivism: thinking takes place in an inner subjective world, divorced from the outer objective reality and knowledge is constructed there by the individual through material and mental acts. In a phenomenological framework (constitutionalism) the fundamental unity between human beings and the world in which they live is assumed. Knowledge represents ways of seeing, experiencing, thinking about the world and it is constituted through the internal relation between the knower (subject) and the known (object)"(p.37)*

The world is not constructed by the learner, nor is it imposed upon him/her; it is constituted as an internal relation between the world and the learner. There is only one world, but it is a world we experience, a world in which we live, a world that is ours. As Ramsden *et al.* (1993) states:

> *"There is only one world which we have access to – and that is, the world as experienced" Ramsden et al. 1993 p303.*

Learning and, therefore, students approaches to learning lie within these experiences.

4.3.2 Constitutionalist epistemology

The most significant difference between constitutionalist and constructivism for the purposes of this study is that from a constitutionalist view, learners are seen to experience what they are learning (knowledge) in a small and identifiable range of different ways. If for example you were to take 20 students learning about projectile motion. The students could experience this phenomenon in several identifiably different ways. From a constructivist perspective each of the 20 students would have individual conceptions of projectile motion but from a constitutionalist perspective learning is a relationship between the learner and what is being learned. As the learner is involved in this relationship, this takes into the account the constructivist view point of prior experiences, knowledge and approaches. Each of these is simultaneously present during this relationship, which is an experience. As Marton & Neuman (1989 p.37) point out “An experience always takes someone to do the experiencing and something to be experienced; the experience comprises a relation between them. This is why this school of thought can be called constitutionalism”. But during this experience, one or more of these aspects may be more to the foreground of our awareness, while other aspects may be more to the background. From a constructivist perspective, the students construct an independent reality or, as per example above, an independent conception of projectile motion because they, as the learners, are not having a relationship with what is being learned. It is merely a concept that they are constructing which when added to their previous constructs creates an independent reality. This independent reality or conception of projectile motion can then be tested against the external world to see if it fits the constraints of this external world. Hence, there may be 20 different conceptions of projectile motion but they all have to be tested against the same external world which will result in an eventual convergence of conceptions. From a constitutionalist perspective there is no external world instead there is an internal relationship between the individual and the world. According to Trigwell & Prosser (1997b):

> *Individuals and the world are internally related through the individuals' awareness of the world. Mind does not exist independently of the world around it. The world is an experienced world. There is not an internal structure of the mind which is composed of, or can be modelled in terms of, independently constituted parts. Thus perceptions, approaches and outcomes are not independently constituted but for analytical and heuristic purposes are considered to be simultaneously present in the students' awareness.(p.242)*

Therefore students will not all experience the same learning and teaching situation in the same way nor will they approach their learning in the same way, even within the same context. The awareness discussed in the quote has been defined by Marton (2000 p.113) as not a dichotomy, i.e. unaware and conscious, but as “everything that is experienced simultaneously in whatever way it is experienced”. So the learner is simultaneously aware of all aspects of the situation or of a phenomenon, but certain aspects come into focus or become focal (figural), whereas other aspects recede into the background.

Awareness, also according to Marton & Booth (1997 p.87), has "both structural and referential dimensions". So when students are experiencing their learning they would be aware of all the aspects of learning but with certain aspects receding to the background and some coming to the fore. Of these aspects, one would be the phenomenon of a student's approach which students would be aware of (perhaps not explicitly) which has both structural and referential aspects. The structural aspect involves "discernment of the whole from the context (external horizon)" (Marton & Booth 1997 p.87) so, in my example, it would be the discernment of an approach to learning from the context of learning. However, the structural aspect also involves the "discernment of the parts and their relationships within the whole [internal horizon]" (Marton & Booth 1997 p.87). So the structural part, in my example, would be the discernment of the different parts of that approach to learning and the relationship of these parts to one another. At the same time as discerning the approach to learning from that context and intertwined with those structural aspects, is the referential aspects which in my example, would be the intention behind the approach to learning. The external horizon is all that surrounds the experienced phenomenon and the internal horizon are the discerned parts of the experience, the relationship between them and the relationship with the whole. By experiencing the parts and whole and the relationship between them, it is possible to discern further degrees of meaning.

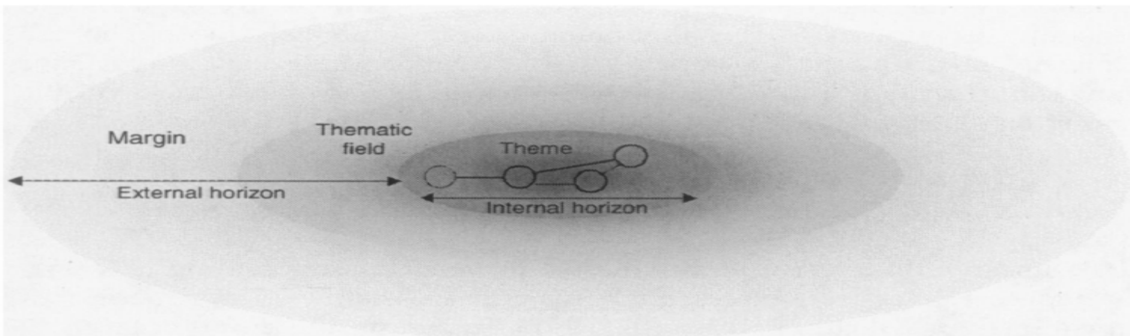


Figure 4.1 External and Internal Horizon – Source taken from Cope & Prosser 2005 p. 349

Referring to figure 4.1 the internal horizon which contains the themes of expanding awareness contains "The aspects of the phenomenon simultaneously present in the theme of awareness (the circles in the centre) and the relationships between these aspects and between the aspects and the phenomenon as a whole." (Cope & Prosser 2005 p.350). The external horizon in the diagram 4.1 is indicated by the margin and the thematic field and according to Cope and Prosser: "Consists of the thematic field and the margin, that is, all aspects that are part of awareness at a particular instant but which are not thematic. The external horizon as an area of awareness forms the context in which the internal horizon sits." (Cope & Prosser 2005 p.350).

To further exemplify the internal and external horizon Marton & Booth (1997 p.87) use the analogy of being able to see a deer in a dark wood:

> *"To see it at all we have to discern it from the surrounding trees and bushes, we have to see its contours, its outline, the limits that distinguish it from what surrounds it. But seeing its contours as contours, as the contours of a deer implies that we are already identified it as a deer standing there, which is exactly where the enigma of what it takes to experience something in some context lies. On the one hand, in order to see something as something we have to discern that something from its environment. But on the other hand, in order to discern from its environment we have to see it as some particular thing, in other words assign it a meaning. Structure presupposes meaning, and at the same time meaning presupposes structure. Meaning also always presupposes discernment and discernment always presupposes variation (Marton & Tsui, 2004). The two aspects, meaning and structure, are dialectically intertwined and occur simultaneously when we experience something."*

As stated previously, when a person has an experience, they are simultaneously aware of all aspects of that experience. However, those aspects are discerned and may become the objects of focal awareness and are thematised (the theme), while other aspects of the experienced world recede to form the background to the theme, and so are unthematised (the thematic field) (Marton 2000). This theory was influenced by Gestalt theory which was discussed in the cognitivist learning theory section 2.2.3.

Linder & Marshall (2003 p.274) provide two physics-related problems to illustrate the distinction between the theme and the thematic field. The first problem being:

> *A small insect flies directly into the windscreen of a bus traveling down a freeway and is immediately killed as it is splattered onto the windscreen. Compare the relative*

size of the impact force experienced by the insect and the bus respectively for the period of impact.

They describe that in this case certain aspects may be discerned by an individual, such as the bus, the insect, the relative velocities of the two, Newton's laws, ideas about force and momentum, intuitive thoughts about force and motion, and these make up the thematic field of the situation. The theme would comprise of those aspects of the thematic field which were brought into focal awareness and an individual's experience of this problem may differ depending on which critical aspects were brought into focal awareness. Therefore, according to Linder & Marshall (2003 p. 275):

Learning is about changing those aspects of the phenomenon that are present in the theme, and the role of teaching, then, would be to focus on the educationally critical aspects of a phenomenon, and in doing so, widen the space of variation for the learner.

So there are a limited number of qualitatively different ways which something that is experienced can be understood in terms of which constituent parts or aspects are discerned and appear simultaneously in people's awareness. A particular way of experiencing something reflects a simultaneous awareness of particular aspects of the phenomena. Another way of experiencing it reflects a simultaneous awareness of what aspects or more aspects or fewer aspects of the same phenomenon are experienced. More advanced ways of experiencing something are, according to this line of reasoning, more complex and more inclusive than less advanced ways of experiencing the same thing. More inclusive and more specific ways both imply that more simultaneously experienced aspects constitute constraints on how the phenomenon is seen (Marton & Booth 1997). Therefore, it is the variation in the way that aspects of a particular phenomenon or object are discerned that constitutes the learner's experience of that phenomenon (Linder & Marshall 2003).

This theory of variation and awareness (Marton & Booth 1997; Trigwell & Prosser 1997; Bowden & Marton 2004; Marton & Tsui 2004 and Marton & Pong 2005) has become the cornerstone of the 'new' phenomenography (Linder & Marshall, 2003 and Pang 2003) which has shifted recently from methodological considerations to theoretical considerations. Pang (2003) suggests that variation theory has given ontological significance to the ways of experiencing something.

If learning is the discernment of the variation of critical aspects of an experience and learning can be divided into the sub-categories of how (approach) and what (concept) with each of these sub-categories having both structural and referential aspects, then an investigation into students approaches to learning would be to examine the variation in the critical aspects of the strategies students adopt to their learning (structural) and the critical aspects of the intention underpinning these approaches (referential). With this aim in mind, I felt that a constitutionalist epistemology was the most appropriate form in which to ground my research. Trigwell & Prosser (1996) argued that research of a relational nature, such as this research into learning, is entirely consistent with this constitutionalist perspective. It was from this perspective that I formulated the research questions to address the research problem and I naturally chose the phenomenographic methodological approach out of which constitutionalism as a theory of knowledge and variation theory as a theory of learning were derived. In the following section a detailed overview of the methodological assumptions of phenomenography is provided and the reason for its use in this study is discussed.

4.4 Research Methodology

As a strategy of inquiry or methodology with which to answer the research questions, phenomenography was chosen. It has become a popular methodology in education research as it aims to identify variations in the experiences, perceptions or understanding of a phenomenon by a specific group of individuals.

4.4.1 Phenomenography

A wide range of research within the phenomenographic tradition has given accounts of the different ways in which people experience various phenomena in the world. The adoption of this methodology came about due to the desire to understand why some students were better learners than others. Phenomenography was developed, in the early 1970s by Ference Marton and colleagues and has its origin in the approaches to learning work from the much discussed Marton and Saljo papers (Marton & Saljo 1976a, 1976b). Although the approach to learning research was not carried out using a phenomenographic method, it did explore the variation in students' approaches to their learning. Later, it was Marton (Marton 1981) who defined it as the empirical study of the variation in the ways in which people experience, perceive, apprehend, understand and conceptualise various phenomena and aspects of the world around us. It has become very popular in the last two decades especially in Australia, UK, Sweden and Hong Kong (Dahlgren 1980; Linder & Erickson 1989, Bowden *et al.* 1992; Booth 1992 and Trigwell et al 2000).

Although the relationship between phenomenology and phenomenography has been regarded as unclear (Greasley & Ashworth 2007), and phenomenography is sometimes seen as a subset of phenomenology, phenomenography did not emerge or derive from phenomenology (Uljens 1996 and Svensson 1997). Phenomenology aims to capture the richness of experience, the fullness of all the ways in which a person experiences and describes the phenomenon of interest. Taking a phenomenological approach is to step back from ordinary assumptions regarding things and to describe the essence of experience as they appear rather than attempt to explain why they appear in that way, whereas phenomenography aims to find out the qualitatively different ways of experiencing or thinking about some phenomena (Marton 1994). Furthermore, this phenomenographic approach assumes that there are a limited number of qualitatively different ways in which different people can experience a phenomenon. The difference between the two methodologies can be seen in the difference in the questions the two types of researchers would ask:

> *"The phenomenologist might ask, "how does the person experience her world?" the phenomenographer would ask something more like, " what are the critical aspects of ways of experiencing the world that make people able to handle it in more or less efficient ways?"" Marton & Booth (1997 p.117).*

This experiencing of the variation in critical aspects of an experience is known as "variation theory". Different people will not experience a given phenomenon in the same way, rather, there will be a variety of ways in which people experience or understand that phenomenon. The objective of a phenomenographic study is to reveal the variation, captured in qualitatively distinct categories, in ways of experiencing the phenomenon in question, regardless of whether the differences are differences between individuals or within individuals. In other words, a description of a way of experiencing might apply in some sense across a group or, there again, might apply to some aspect of an individual to the extent that the group represents the variation of individuals in a wider population (or is a theoretical sample of the population). The categories of description can also be said to apply to the wider population, example: Marton and Saljo's original approaches to learning. Similar variation might even hold across different cultures. The outcome of phenomenographic research is, therefore, a list or description, of the qualitative variation in the ways the sample participants (e.g. students) experience an object of study, a phenomenon, a concept or an activity (e.g. their approaches to learning) (Maton 1986). These descriptions are relational that is, "a person's experience is strongly influenced by their intentions and that the context in which the phenomena are embedded, in turn, influence the experience. The intent of the analysis is to depict the 'thinkers' understanding of that which is thought about" (Johansson *et al.* 1985 p.247). For instance, from the PERG research group (Walsh 2008) phenomenographic research showed the limited variation in students' approaches to problem solving in the context of a first year physics course. From the phenomenographic perspective, the approaches are also conceived of as relational in nature. The approach adopted by a student in this particular context is a function of both the student and the context.

One of the assumptions of phenomenography is that a single person may not express all aspects of a phenomenon (Sandberg 1995). As Sandberg states, 'in some cases a specific conception cannot be seen in its entirety in data obtained from a single individual, but only within data obtained from several individuals' (Sandberg 1995 p.158). Booth (2001) goes further and explains that the object of analysis is the ways of experiencing at a collective level. The results are not expressions of individual difference; they are expressions of the potential ways of experiencing a phenomenon that might be found in a collective of people of similar characteristics separate to those involved in the data collection. A good example of this would the Marton and Saljo approaches to learning, which has been applied to numerous groups outside of the original data although not always in the same context as argued previously.

Furthermore, as mentioned previously in the section on awareness, a particular way of experiencing something reflects a simultaneous awareness of particular aspects of the phenomena (Another way of experiencing it would be for others to have awareness of other aspects or more aspects or fewer aspects of the same phenomenon that is being experienced). More advanced ways of experiencing something are, according to this line of reasoning, more complex and more inclusive than less advanced ways of experiencing the same thing. More inclusive and more specific both implying more simultaneously experienced aspects of how the phenomenon is seen (Marton & Booth 1997) or as Marton (1994) states different ways of experiencing different phenomena or concepts are representative of different capabilities for dealing with those phenomena or concepts and that some ways of dealing with the phenomena or concepts are more productive than others. Thus, the conceptions, or "ways of experiencing" and their corresponding descriptive categories are not only related, but may also be hierarchically arranged and it is this hierarchy that displays the relationship between the categories. The system of categories presented can never be claimed to form an exhaustive system, but the goal is that they should be complete in the sense that nothing in the collective experience as manifested in the population under investigation is left unspoken. The ordered and related set of categories or descriptions is called the "outcome space" of the phenomenon or concept being studied. Marton (2000) states that the outcome space describing the different ways in which an object (or phenomenon or concept) is understood or experienced constitutes that object, as the object cannot be defined independently of the way in which it is experienced.

Developments in the field of phenomenography have led to a new phenomenography whose aim is to characterise particular ways of experiencing. As Pang (2003 p. 152) states

> *The new phenomenography studies both the variation among the different ways of experiencing something as seen by the researcher, and the variation among the critical aspects of the phenomena itself as experienced by the learner.*

A way of experiencing a phenomena or concept can be characterised by the dynamic structure of an individual's awareness, and that awareness has both a structural and referential aspect. Therefore, categories describing the variations in how something is experienced will have both structural and referential components and the categories differ from each other depending on the critical aspects which are discerned and kept in focal awareness simultaneously. Marton & Booth (1997) state that "a way of experiencing something springs from a combination of aspects of the phenomenon being both discerned and presented in focal awareness simultaneously. An aspect is…a dimension of variation" (p.136). The highest hierarchical category will consist of discerned key aspects which are in focal awareness simultaneously whereas low categories may correspond to few or no aspects being discerned, intermediate categories relate to more aspects being discerned and perhaps being used in sequence (Stephanou 1999). The categories are hierarchical in the sense that if you have categories A, B and C then A implies B and C. In turn then B implies C so you have found three hierarchical approaches to learning then the category at the top of the hierarchy will encompass the ability of the student to employ two lower ranked categories for example Walsh's (2008) categories of variations in approaches to problem solving.

There are certain criteria for the quality of a set of descriptive categories, which can be seen as methodologically grounded. The first criterion that can be stated is that the individual categories should each stand clear in relation to the phenomenon of the investigation so that each category tells us something distinct about a particular way of experiencing the phenomenon. The second is that the categories have to stand in a logical relationship with one another, a relationship that is frequently hierarchical. Finally, the third criterion is that the system should be parsimonious, which is the say that as few categories should be explicated as is feasible and reasonable, for capturing the critical variation in the data.

However, in phenomenographic analysis there is no attempt to 'fit' the data into pre-determined categories. Some phenomenographic researchers consider that the categories are constructed from the data and others believe that they are constituted within the data and are, therefore, discovered (Hasselgran & Beach 1997 and Walsh 2000). The latter corresponds to my own view and although I began by assuming that a limited number of conceptions and approaches could be found, the data was examined as a whole and during the analysis I endeavoured to incorporate all aspects of the data.

4.4.2 Summary of phenomenography as a methodology

Trigwell (2000) identified five points describing phenomenography. First, phenomenography is non-dualist. In other words, reality is not seen as being 'out there' but instead is seen as being constituted by the relation between the individual and the phenomenon. Secondly, it is qualitative rather than quantitative. Thirdly, it is considered second order rather than first order meaning it focuses on the individual rather than the relationship between the individual and the world. Fourthly, it focuses on the variation in the ways people experience a phenomenon, and finally, it includes a range of an individual's experiences in the form of categories. For this methodological approach, the aim is to reveal the variation, captured in qualitatively distinct categories (an outcome space), of ways of experiencing the phenomenon in question. However, it is more than just identifying these conceptions and 'outcomes spaces', the analysis involves looking for their underlying meanings and the relationship between them (Entwistle 1997). As Akerlind (2005b) states:

> *The aim is to describe variation in experience in a way that is useful and meaningful, providing insight into what would be required for individuals to move from less powerful to more powerful ways of understanding a phenomenon. (p.72)*

For instance, one might conduct phenomenographic research to study the qualitatively different ways students' approach problem solving and the different ways they perceive conceptual knowledge and, in each case, an outcome space is developed. Then the researcher can examine the two outcome spaces to find the relationship between how students approach problem solving and how they perceive conceptual knowledge. Indeed, this type of relational phenomenographic study has been carried out by a number of researchers (Biggs 1979; Ramsden 1992; Marton *et al.* 1997 and Marton & Saljo 1967).

4.4.3 Criticisms of phenomenography

Marton (Marton & Booth 1997), as discussed already in this chapter, broke learning down into "how and what" aspects and it has been argued (Fleming 1986) that when students are asked to describe their learning, that their descriptions are rarely able to capture the "how and what" dimensions completely. The criticism goes further to argue that the descriptions would not even convey the structural and referential aspects of one of these "how and what" dimensions and instead the descriptions the students offer are only fragments of these dimensions.

Marton *et al.* (1993) rebuttal to this type of argument is that it is okay to have these fragments as long as it is the researchers job to analyse just what these fragments are fragments of. To do so, Marton advocates the use of the 'structure of awareness' theory that has already been discussed in section 4.3.2. To restate the theory, it implies that an individual's awareness is likely to include aspects of the phenomenon initiated by the context in which it is situated with some aspects being more critical than others. In other words, awareness is understood as the totality of a person's experiences of the world, at each point in time (Marton & Tsui 2004). For each different situation students awareness will focus on different aspects but in a phenomenographic interview where a student is asked to express their experiences of a phenomenon, within this expression can be found the critical aspects of that phenomenon that they are aware of.

Another one of the criticisms of phenomenography is its tendency to connect peoples' experiences with their accounts of their experiences. Saljo (1997) and Marton (1994) reported that people's 'accounts' of their experiences with a particular phenomenon are not always comparable to the ways in which they actually experience the phenomenon. However, the only way we can begin to understand these experiences are to ask each person to describe them. There is no other physical way to examine this. Observations will not tell us how people experience a given phenomenon, hence the reason the observation protocol in this research project is used only to identify actions with no interpretation of the intention behind them.

Another concern regarding phenomenography is whether researchers using it can be impartial 'neutral foils' – while interviewing and analysing research data (Webb 1997). There is a similar criticism in relation to ethnography. This may be particularly true for approaches to learning research due to prevalence of deep and surface categories appearing in most reported research. Webb calls for researchers to make their views and beliefs known from the start, because readers of the research need to be informed about all the variables that have affected the study's results. Akerlind (Akerlind 2006) believes that these criticisms may be founded on a fundamental misunderstanding of the approach. Ashworth & Lucas (1998) call for researchers to be particularly careful in recognising their own tendencies and biases which may influence the research findings. Akerlind (2006) addresses these issues generally by highlighting the variations in the ways in which phenomenographic research and analysis has been used and subsequently described in numerous scholarly contributions to the literature.

4.4.4 Rationale and use of phenomenography in this research

For my research, in a phenomenographic sense, at least, I am interested in examining the variation in the critical aspects of students' approaches to their learning in the context of a problem-based learning physics course. Although I feel that it is appropriate to conduct this research using a phenomenographic approach, it is not a "pure" phenomenographic approach which is the position with most research in the educational domain that has the intention of having practical outcomes. Pure phenomenography is not appropriate as the aim is to examine students' approaches to learning in order to make further use of the outcomes in future learning and teaching contexts. Therefore, I am using a variant of phenomenography called 'developmental phenomenography" (Bowden 1995). In developmental phenomenography (Bowden & Walsh 2000) the research is designed with the intention that there will be practical outcomes and implications for learning and practice (Bowden & Green 2005).

Bowden discusses his groups' use of developmental phenomenography on a number of studies (p. 146):

> *I describe the kind of research that I do as developmental phenomenography because it is undertaken with the purpose of using the outcomes to help the subjects of the research, usually students, or others like them to learn. The insights from the research outcomes can help in the planning of learning experiences which will lead students to a more powerful understanding of the phenomenon under study, and of other phenomena like it. The outcomes from these research studies can also be used to develop generalisations about better and worse ways to organise learning experiences in the particular field of study.*

Bowden and his research group have carried out a number of investigations into students' experiences and understanding of some key concepts and principles in physics using a developmental phenomenographic approach (Bowden *et al.* 1992; Dall'Alba *et al.* 1993; Walsh *et al.* 1993 and Ramsden *et al.* 1993). They (Bowden *et al.* 1992) also used this research methodology to investigate the understanding of displacement, velocity and frames of reference in a large group of students'.

For examples of phenomenographic research closer to the goal of this research project we can look to the original study by Marton and Saljo (1976a, 1976b) which although it did not use a phenomenographic method, per se, it did examine the variations in students' approaches to their learning. In a study set in the context of problem-based learning and examining approaches to learning using a phenomenographic method, the previously referenced Ellis *et al.* (2007) investigated students conceptions and approaches to learning within a pharmacy course. The authors through the analysis of interview transcripts and questionnaires, discovered five categories which described the variation in the way students approached their learning in a problem-based pharmacy course. Ramsden (2002); Entwistle & Ramsden (1983); Prosser & Trigwell 1999 and Laurillard 2002 have also used phenomenography in research on learning and teaching in the past thirty years. The significance of these studies was that the researchers were all interested in investigating how the critical aspects of the phenomena as experienced by students' varied. In this research, the objective was to examine how the critical aspects of the students' awareness varied with respect to their approach to problem-based learning and therefore a phenomenographic methodology was used to undertake this research.

4.5 Data collection and analysis methods

This section presents an overview of the methods chosen to collect data for the study. Given the philosophical underpinnings laid out in the previous sections, it is obvious that the majority of this research favours the use of qualitative methods but some quantitative methods based on qualitative research are also employed in order to triangulate the results. In a sense, the methods were used in a hierarchical fashion with the dominating method being the phenomenographic methodology employing the open and deep interview approach, which is carried out in a dialogical manner (Booth 1997 and Akerlind 2006). The primary method of investigation, the interview, is discussed first followed by the other methods of investigation employed in this study.

4.5.1 Individual Interviews

There are certain limitations in using interviews as the primary source of data collection; however these pitfalls can be avoided with proper preparation, for example overcoming the interviewer's perceptions and bias. In relation to finding out a student's experience of their approach to learning in the context of a problem-based learning physics course, the only route into the student's own experience is that experience as expressed in words or acts, hence why the interview is the main source of data for this project. Semi-structured interviews were conducted in a conversation and discussion manner. The use of this approach provides a degree of structure to the interview while retaining flexibility to permit individuals to direct the interview. Ashworth & Lucas (2000) suggest that the researcher's task is to achieve 'empathy and engagement' in an interview situation so that the participant is given the maximum opportunity to reflect on her/his own experience, and feel comfortable in talking about all of the aspects of the phenomenon of which she/he is aware. This, I hoped, would give each participant an opportunity to talk at length about problem-based learning and provide me with a rich source of data. The interview was split into two parts with questions designed to be prompts so that participants could explore all areas of interest but also there were straight forward enquiry questions to obtain information such as previous level of physics experience. I decided to adopt the semi-structured type of interview for three main reasons. First, this approach provides not only extensive records of a participant's conceptions and experience, but also provides extensive data for evidence to support an argument. Secondly, it allows enough flexibility for the researcher and the participants to clarify meaning and explore fully the issues that arise during the interview process. Thirdly, using open ended interviews depends very much on the ability of participants to recall and express extensively their beliefs and experiences. During the three pilot interviews students were found to be unwilling or able to expand their opinions without sufficient probing and so an open-ended structure seemed inadequate for the data sought. Another outcome of the pilot interviews was the inability of the students to distinguish between what they themselves did and what the group did when describing the process of solving problems in problem-based learning. This was counteracted by introducing a written question before the interview started, asking the students to reflect on what they did during the first session of problem-based learning with the answer to the question starting with "I would…" This got the students into the right mind frame to answer the interview questions.

On average the interview would last about 60 minutes with the notable exception of the mature students who took up to 90 minutes to complete the interview. This was due to the fact that the mature students were more open to elaborating on their responses. The interviews were video recorded and then transcribed verbatim. Great care was taken so that physical responses of the participants, such as facial expressions, body movements and laughter were also recorded.

A criticism of interviews in which the researcher asks predetermined questions is that, by providing a structure for the interview, the researcher loses the opportunity to understand how the participants might choose to organise the topic being discussed. Whilst this is a reasonable criticism, the semi-structured interview was chosen in this particular study because it enabled me to collect the data which could be compared across participants, and in addition, provided a focus on the question being investigated.

Saljo, since his earliest work with Marton, has questioned the validity of using interviews for the purpose of investigating learning and teaching, arguing that the context might be influencing the nature of the responses given. Saljo (1997) suggests that expressions in an interview indicate 'the attempt to fulfil one's communicative obligations when being asked a question or a wish not to lose face when confronted with an abstract and maybe difficult question' (Saljo 1997 p. 177). We learn about the socially appropriate ways of talking about our experience of a phenomenon, and we frequently borrow accounts from stories which other people have told us. It is assumed, therefore, that it is difficult to disconnect what is said in an interview from its communicative function in that particular context. Kvale (1996) also argues that the interviewee's statements are co-authored. Despite these criticisms, the interview for me remained the most appropriate method of data collection for this study. If the goal of the research is to find students approaches to learning, then it would seem appropriate to ask those students how they approached their learning. The last sentence should not be viewed as an over simplification of the research method as I did not simply ask students how they approach their learning. Many of the criticisms mentioned above can be addressed by ensuring that the right questions are asked and that the interviewer is "qualified" to interview. In other words the interviewer must have a clear understanding of the phenomenographic method and be able to put it into practice using an interview.

Overall the interviews provided data to answer the following research questions:

In the context of the physics problem-based learning course:

- What are the qualitatively different ways in which students approach their learning?
- What are the qualitatively different ways in which students perceive their learning environment?
- What factors within this environment influence a student's approach to learning?

4.5.2 Interview analysis

All of the interviews were then transcribed verbatim from the videotapes. The interviews being videotaped allowed a degree of fullness to the transcriptions which I believe would not have been possible with audio recordings alone. Any vocal tone shifts were recorded as well as hand and face gestures. Therefore, in analysing the data, qualitatively distinct categories emerged that described the variations in the students' perceptions, conceptions and approaches. I believed that a limited number of categories were possible for each research question and that these categories could be discovered by immersion in the data.

A core principle of phenomenographic research is the assumption that categories describing the variation in the ways of experiencing something are related to each other, usually by a hierarchical relationship, as previously discussed (Marton & Booth 1997). However, John Bowden (2005), among others (e.g. Ashworth & Lucas 2000), recommends that the analysis of this structural relationship between the categories be postponed until the overall meaning of the categories has been finalised. This is due to the fact that such structural links between the categories requires the researcher to apply their own perspective and, at all times, during the analysis the researcher's own relationship to the phenomenon or experience must be bracketed. Therefore, all analysis should be based solely on the interview transcripts; as Bowden (2005 p.15) said "if it is not in the transcript, then it is not evidence". But owing to the fact that meaning and structure are "supposed to be co-constituted in phenomenographic analysis" other researchers warn of the dangers of not considering both meaning and structure simultaneously (Akerlind 2005a p.324). Akerlind (2005b) states that a strong emphasis on structure is necessary, because one of the epistemological underpinnings of phenomenography is that logical relationships exist between different ways of experiencing the same thing. An outcome space is not simply a set of different meanings but should be a logical structure relating the set of meanings. Akerlind (2005b p.72) believes that this is imperative for phenomenographic analysis "because it provides a way of looking at collective human experience of phenomena *holistically*", even though that phenomena may be experienced by different people in different ways in various contexts.

Another reason that Akerlind (2005b) believes that structure and meaning should be co-constituted from the data is that the resulting outcome space will have more practical application by making the variation in the experience meaningful. Distinguishing the critical aspects in the variations in the ways of experiencing a phenomena and, thereby, highlighting the structure of these critical aspects, allows for a better understanding of how individuals could be helped to move from a lower hierarchical category to a higher hierarchical category. Therefore, Akerlind (2005c, p.122) recommends, in searching for dimensions of variation, that "themes of expanding awareness" be identified and discovered within the data:

> *What I have called 'themes of expanding awareness' may be seen as representing structural groupings of dimensions of variation, highlighting the structural relationships between different dimensions. To be accepted as a theme, I required empirical as well as logical evidence of inclusive awareness of each dimension comprising the theme.*

In addition to the emphasis on meaning and structure in the outcome space, due to the assumption that when an individual is experiencing something the structure of their awareness can also be categorised by the two internally related dimensions, structural and referential aspects. During the clarification of the categories the 'how' and the 'what' students were saying are focused upon. The 'how' in this case is 'how is the explanation given?' and the 'what' is 'what is focused on?' (Trigwell 2000).

Marton (1986) states that phenomenography provides categories that are qualitative, experiential, relational and content-oriented. Svensson (1997 p.171) further outlines the methodological assumptions involved in the analysis of phenomenographic research by arguing that the categories of description must be based on "exploration of delimitations and holistic meanings of objects as conceptualised" and also that categories are based on "differentiation, abstraction, reduction and comparison of meaning". The categories are not constituted from every detail in the interview transcripts, rather they represent a small number of holistic meanings with a focus on key aspects of the experience which serve to link and separate the different categories of description. The process of analysis calls for the researcher to differentiate between critical variation and non-critical variation, with critical variation being described as "that which distinguishes one meaning or way of experiencing a phenomenon as qualitatively different from another" (Akerlind *et al.* 2005 p.82), whereas non-critical variation is described as occurring within a way of experiencing and, therefore, does not distinguish between ways of experiencing.

However, throughout the initial stage of examining the transcripts, I endeavoured to keep a high degree of openness to any possible meanings. The transcript was considered as a whole. I also felt it was important to examine the transcripts as a group and not as individual samples as phenomenographic research aims to explore the range of meanings (the pool of meaning) within a group and the categories which constitute the outcome space represent the range of ways of experiencing a phenomenon. As Aklerlind (2002) states:

> *The aim is not to capture any particular individual's understanding, but to capture the range of understandings within a particular group. The interpretation is, thus, based on the interviews (more precisely, the interview transcripts) as a holistic group, not as a series of individual interviews. This means that the interpretation or categorisation of an individual interview cannot be fully understood without a sense of the group of interviews as a whole.*

During the first iteration of analysis, I looked for both similarities and differences among transcripts, selecting significant statements and comparing these statements in order to find cases of variation or agreement and thus grouping them accordingly. Marton & Booth (1997) describe phenomenographic categories of description as being constituted by considering variation, discernment and simultaneity (see section 4.3.2) and this is what I endeavoured to do at all times. I read the interview transcripts many times, each time with a particular aspect of the interview theme in focus and this was carried out using an essentially two-stage analysis. The first stage involved identifying and describing the overall meaning of approaches or conceptions by highlighting and separating the section of the transcripts according to the themes which were apparent, thus representing the 'how' aspect. The second stage, which represented the 'what' or structural aspect, involved identifying what was focused upon within each overall meaning and searching each preliminary category and the transcripts as a whole for themes of expanding awareness.

Through this process initial hierarchical categories were constituted that described the variations in the ways that these students' approach their learning in problem-based learning. Once this initial categorisation was complete, a sample of the interview transcripts was given to one other researcher (BB) from the Physics Education Research Group who then independently carried out a similar analysis of those transcripts. I then met with the researcher to discuss their categories and their interpretation of the answers and through this discussion the categories were then revised until a consensus was reached about the final set of categories. Bowden (2000, 2005) strongly advocates a group process in phenomenographic analysis, whereas Akerlind (2005a, 2005b) suggests that it is more than possible to carry out reliable and valid phenomenographic research as a sole researcher. I was the primary researcher in this study and, therefore responsible for carrying out the majority of the analysis; however, I felt that the input of another group member would add validity and reliability to the results.

With the initial categories in mind, I re-examined the interview transcripts to determine whether the categories were sufficiently descriptive and indicative of the data. If there were cases that I felt could not be described by a category, the categories and the interview transcripts were re-examined and, in some cases, the descriptions were altered to ensure every aspect of the experience under investigation was described. At this stage, extracts from the transcripts were sought to support the descriptions of the categories, which I felt gave substance to the categories. This iterative data analysis procedure is consistent with a phenomenographic approach (Marton & Pong 2005; Akerlind 2006), as Marton (1986 p. 43) states “definition for categories are tested against the data, adjusted, retested, and adjusted again”. Also as Marton & Booth (1997 p.134) eloquently state “the data shimmers in the intense light of our analysis”. For each research question, an outcome space was developed that included the minimum number of categories, which explained all the variations in the data. Once I had defined the stable outcome spaces I then analysed how the structure of the individual categories logically related to each other and how the outcomes spaces related to each other. This entire process is described in more detail in Chapter 5 while outlining how each outcome space was constituted.

4.5.3 Observation

In order to examine the actions of students within a problem-based learning group, 24 students over the course of two years, in six separate groups were recorded working in their problem-based learning sessions over an eight week period which covered the first year mechanics part of the course. These recordings were then shared among six members of the Physics Education Research Group (BB, RH, JT, LW, CG and PI) in three groups of two with the intention of each pair examining a group solving three separate problems at three different parts of the year. So each pair analysed a group solving a problem when they first entered problem-based learning, half way through the mechanics course and near the end of the mechanics course. Each researcher independently viewed the tapes and listed each student’s main actions of the way in which they interacted within the group. The researchers, who were all experienced physics problem-based learning tutors, used their own value judgements to qualitatively distinguish between actions of a similar nature. For example, when a student asks a question this would be listed as an action, but the quality of the question can vary so it was important to be able to qualitatively distinguish between types of questions. It was, therefore, down to the researcher’s experience to make value judgements on the quality of the questions. When each researcher had completed their list of actions they met to compare and contrast between their lists of actions and a negotiation on their individual value judgements took place if it was needed and resulted in researchers often reviewing the tapes. As the primary researcher I ensured that I kept an overview of all the pairs to ensure consistency. After this process, the group of researchers as a whole met and discussed and negotiated a terminology for actions of a similar nature but labelled differently. At the end of this process, a list of actions was prepared in relation to each student describing their behaviour over three problem sessions and with these lists analysis could begin. The final analysis process of the observational findings was solely carried out by myself as I examined students actions for trends and created an overview of students actions for each problem solving session which was validated by another researcher. Further discussion of the method can be found in Chapter 6.

4.5.4 Force and Motion Conceptual Evaluation

As discussed in Chapter 2, research based diagnostic tools have been widely used to assess conceptual understanding and conceptual learning gains in introductory physics students over the past 18 years. In order to set the conceptual knowledge context for this study and to quantitatively determine if gains in learning (as measured by the diagnostic tool) had been achieved through instruction, one such diagnostic tool was employed for this research study. That tool was the Force and Motion Conceptual Evaluation.

Thornton & Sokoloff (1998) developed the Force and Motion Conceptual Evaluation (FMCE) as an instrument "to evaluate student learning in introductory physics courses" (p. 338). A copy of the FMCE is shown in Appendix E. The instrument is a research based multiple-choice assessment that was designed to "probe conceptual understanding of Newtonian mechanics". The FMCE consists of 47 multiple-choice questions, with all of the questions written in "natural language" and as mentioned previously, many include pictorial representations. The FMCE is structured into clusters of questions associated with a particular situation. Figure 4.2 overleaf is an example of a set of questions from the evaluation and these questions are referred to as "the coin toss"' question.

Questions 11-13 refer to a coin which is tossed straight up into the air. After it is released it moves upward, reaches its highest point and falls back down again. Use one of the following choices (**A** through **G**) to indicate the force acting on the coin for each of the cases described below. Answer choice **J** if you think that none is correct. **Ignore any effects of air resistance.**

A. The force is **down** and constant.
B. The force is **down** and increasing
C. The force is **down** and decreasing
D. The force is zero.
E. The force is **up** and constant.
F. The force is **up** and increasing
G. The force is **up** and decreasing

______11. The coin is moving upward after it is released.
______12. The coin is at its highest point.
______13. The coin is moving downward.

Figure 4.2: Sample set of questions from The Force and Motion Conceptual Evaluation

In general, the inventory is designed to illustrate whether students:

- have a Newtonian view of the world;
- have a non-Newtonian view of the world;
- are developing some Newtonian views.

As stated in Chapter 3, the FMCE is similar to the Force Concept Inventory (FCI), (Hestenes *et al.* 1992) and the decision to employ the FMCE as a method of investigation in this research was an informed choice. Both tests have been used extensively as evaluation tools (Cummings *et al.* 1999; Wittmann 2002 and Redish, 2003), but while the FMCE does not cover as much material as the FCI, it uses more questions for each concept and approaches them from a number of different contexts. The FMCE also places more emphasis on students' understanding of graphical representations of velocity, acceleration, and force. Redish (2003) reports on studies carried out by Ron Thornton who found strong correlation between results on the FMCE and on the FCI. Figure 4.3 shows scatter plots of pre- and post-FCI verses FMCE scores (Redish 2003 p.104).

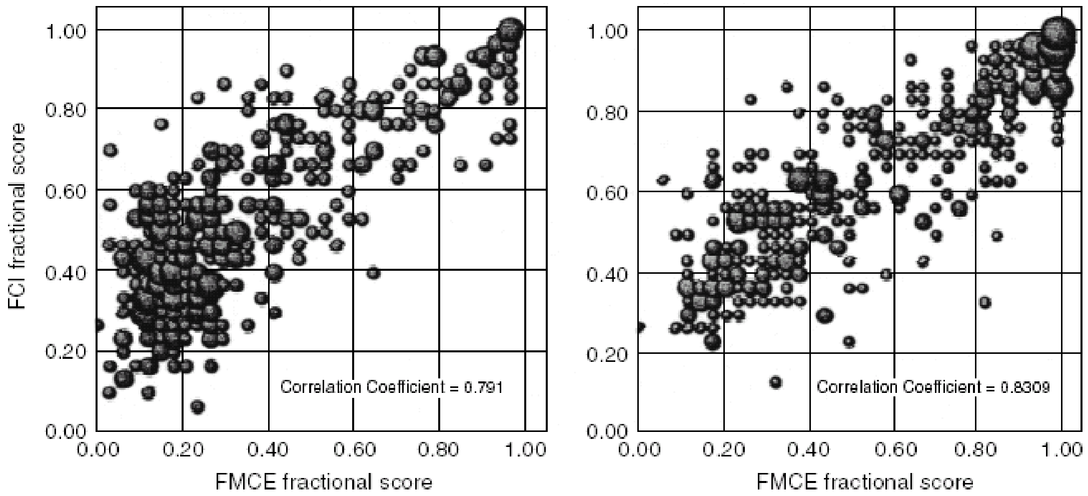


Figure 4.3: Scatter plot of FMCE versus FCI scores pre (left) and post (right). The size of the markers indicates the number of students with those scores (Redish, 2003)

To test the validity of the instrument, Thornton and Sokoloff have evaluated a large number of physics students at many colleges, universities and high schools with the FMCE and compared student responses on multiple-choice versions of the FMCE and versions that consisted of open-ended questions with explanation. They also asked additional questions on examinations to compare with the FMCE results. There was a strong correlation between the student responses to the various styles of questions, particularly the multiple-choice and open-ended with explanation versions of the FMCE questions (>90%). In addition, the pre and post instruction results have proven to be very stable and repeatable (Thornton & Sokoloff 1998) when comparing equivalent classes at several different institutions for both traditional and enhanced instruction.

The analysis of the FMCE results was made simple by a Microsoft Excel™ analysis template created by Michael Wittmann (2002). The template allows the user to input students' answers and it then calculates a percentage for each student, as well as the number of questions answered correctly. The template also breaks the questions down into sections, which are 'Velocity', 'Acceleration', 'Force (1,2)', 'Force (3)' and 'Energy'. Force (1), (2) and (3) here refer to questions relating to Newton's three laws of motion. It calculates the percentage correct for each of these. Both pre- and post- data are inserted into the template and the program will then configure the 'matched data', which means it will give a 'match' if a particular student has completed both of the tests. The template then uses this information to calculate the ‘average normalised gain’ overall and for each section, as described above. Richard Hake of Indiana University introduced this ‘average normalised gain’ factor (Hake 1998).

Average normalised gain = actual gain / maximum possible gain,

or

g = (average post-test score - average pre-test score) / (100 - average pre-test score)

Hake defines the normalised gain on the FCI (or FMCE) test to be the average increase in students' scores divided by the average increase that would have resulted if all students had perfect scores on the post-instruction test. Hake (2002) has carried out extensive research using this method and concludes that “the average normalised gain affords a consistent analysis of pre-test and post-test data on conceptual understanding over diverse populations in high schools, colleges, and universities” (p.7). It should be noted here that although the normalised gain has values from 0 – 1 it is represented, for the benefit of clarity, at times during the presentation of the findings in this thesis, as a percentage and this will be highlighted when it occurs.

Further analysis is presented in Chapter 8, along with correlations relating to the individual students attributes. These correlations were carried out in an effort to investigate whether other factors influenced how a student learned or understood physics

4.5.5 Attitudes and perceptions of physics students

As mentioned previously in Chapter 2, students have certain prior conceptions of physics concepts before they receive any instruction in physics. These conceptions are constructed from their interactions with the world. Not only do students’ have theses prior conceptions, but each student also brings to the class, based on his or her own experiences, a set of attitudes, beliefs and assumptions about what sorts of things they will learn, what skills will be required, and what they will be expected to do (Redish *et al.* 1998). These sets of attitudes and beliefs may affect the way a student will behave and contribute in a problem-based learning group. For example, if they had prior experience of physics in the leaving certificate, they may have certain prior perceptions on how to learn physics and some prior conceptions on the inter relationships between concepts and so may be more willing to contribute to problem-based learning. If a student had never been taught physics before, they would still have prior conceptions of the physical world but may be less likely to contribute said ideas in problem-based learning because of their lack of conviction in said beliefs due to not having received any formal teaching in the subject. If a student had an investigative approach to the world, were phenomena that are seen by the person need to be explained, they may be more likely to have a positive attitude to physics and, therefore, positively contribute to problem-based learning or, to give a more simplified example, a student who dislikes physics is unlikely to contribute well or much to problem-based learning.

Traditional methods of assessing these attitudes and beliefs would involve the deployment of structured/semi structured interviews or observations, both of which are being employed in this study. In large scale physics classes this would not be readily achievable due to the numbers and the corresponding time to transcribe interviews and observations. Due to this scaling problem a number of surveys have been developed to assess students' attitudes and beliefs. Examples of such surveys are: The Maryland Physics Expectations Survey (MPEX) (Redish *et al.* 1998), the Epistemological Beliefs Assessment for Physical Science (EBAPS) (Elby 2001) and the Colorado Learning Attitudes about Science Survey (CLASS) (Adams *et al.* 2006). Of the three surveys mentioned only the CLASS will be discussed below. However, it is worth noting at this point, that the MPEX was used initially along with the CLASS but it was decided to use the CLASS exclusively after testing both. The reason for this, and it ties into the previous usage of observation and structured/semi structured interviews, is that the CLASS survey gave a breakdown of the scores into categories and the students' scores in these categories could be used for correlation with the other findings in this research such as perceptions of the learning environment.

4.5.5.1 Colorado Learning Attitudes about Science Survey (CLASS)

It is worth noting that although I stated above that I would only discuss the CLASS in the following the segment, the MPEX is mentioned as the CLASS is based in some part on the MPEX. Adams *et al.* (2006) developed the Colorado Learning Attitudes about Science Survey (CLASS) as an instrument that 'probes' students' beliefs about physics and learning physics, and distinguishes between the beliefs of experts and those of novices. Students are asked to respond on a Likert (five-point agree to disagree) scale to 42 statements. An example statement is:

30. *Reasoning skills used to understand physics can be helpful to me in my everyday life.*

If a student agreed or strongly agreed to this statement, then he/she would score 1 for this statement and so forth. The creators tried to improve on the MPEX questionnaire by tackling such inconsistencies as statements that include two statements in one. These are often misinterpreted by students, but not so by the experts, hence giving the student a lower score. One of the main reasons why the CLASS was used is the use of categories that are "empirically determined groupings of statements based on student responses" (Adams *et al.* 2006 p.1). This means that only categories that stood up to statistical analysis were used in the final version of the questionnaire.

Table 4.1 Categories for CLASS

Categories	**Statements comprising category**
Real World Connection	28, 30, 35, 37
Personal Interest	3, 11, 14, 25, 28, 30
Sense Making/Effort	11, 23, 24, 32, 36, 39, 42
Conceptual Connections	1, 5, 6, 13, 21, 32
Applied Conceptual Understanding	1, 5, 6, 8, 21, 22, 40
Problem Solving General	13, 15, 16, 25, 26, 34, 40, 42
Problem Solving Confidence	15, 16, 34, 40
Problem Solving Sophistication	5, 21, 22, 25, 34, 40
Not Scored	4, 7, 9, 31, 33, 41

The questions can be split into separate categories, which are individually correlated and are shown in Table 4.1 above. Although the names of the categories are just a label placed on them, statements that encompass these categories summarise a student's attitudes towards that particular point of view. For example, the personal interest in physics category is interesting from a group dynamics standpoint because it can give insights into who is interested in both the course and physics in general.

The questionnaire went through a rigorous validity and reliability study (Adams *et al.* 2006) consisting of three steps: First, experts were interviewed and then took the survey; second, students were interviewed to confirm the clarity and meaning of statements; and finally a detailed factor analysis was performed to create and verify existing categories of statements. The validation process included: face validity interviews with and survey responses from the physics faculty to establish the expert interpretations and responses; interviews with students to confirm the clarity and meaning of statements; construct validity-administration of the survey to several thousand students followed by extensive statistical analysis of the responses. This included a detailed factor analysis to create and verify categories of statements; a predictive validity-correlation with students' incoming beliefs; and course performance and concurrent validity-analysis of responses of the survey to show that it measures certain expected results, such as, that physics majors are more expert-like in their beliefs than non-science majors. Revisions were made to the survey based on the results of the interviews and factor analysis and then the above validation studies were repeated with the new version of the survey (Adams *et al.* 2006).

4.6 Research Participants

As of September 2007, when the interviews began, the School of Physics in DIT had three 4-year programmes in which students entered specifically to study physics. These were all level 8 (NQAI) programmes and first year physics was delivered through problem based learning (Bowe 2005, 2006; Bowe & Cowan 2004). There was also a 3-year, level 7 programme, in which the students enter first year to study 'science', and it is only in second year that students choose either physics, chemistry or biology with the physics section of this course also being delivered through problem based learning with Peer Instruction (Mazur 1997) incorporated into the course design. A detailed description of the level 8 problem-based learning course, which was the focus of this research, was given in Chapter 2.

Many of the students entering first year in DIT have not studied physics for the Leaving Certificate and the entry points for the research participants, ranges from 190 and 540. The key demographics of the research participants are discussed later, at the beginning of Chapter 9, where all of the data from the research is presented. All of the students involved in the study were asked to fill out pre and post FMCE, pre and post CLASS survey and most importantly their permission was sought to allow us to record them working in problem-based learning groups. Some of the information obtained from these questionnaires and surveys was used to select the research participants and form the groups they would be in. I tried to obtain a cohort of students with a range of prior experiences and abilities that would function well as a group. However for the third year of the study this proved difficult as many students missed the induction day and so did not fill out the FMCE pre evaluation and so the groups were made up from a limited number of students. Although data was taken for the first year of the study, the data was incomplete as research design was not formulated, and this year of the study was used more for planning for the next two years and getting familiarised with the problem-based learning environment from a tutor's perspective as opposed to my previous experience as a student.

4.6.1 Interview participants

The participants for the interviews were the students who had been video recorded for their problem-based learning sessions. The chosen students were contacted and asked to volunteer for the interviews and only four declined (in fact only one actually declined while the other 3 had dropped out of their respective courses before the end of the mechanics section of the course, the first eight problems), two from each year of the study, which was encouraging as there was no incentive offered. The interviews were carried out over a two-week period following eight weeks of formal instruction in mechanics each year. The participants were all in their first year of study in the programmes previously mentioned and the sample comprised of 15 male and 5 female students, ranging in age from 18 to 27 taken from the two years of separate cohorts of students.

4.7 Ethical Considerations

As the primary focus of this phenomenographic study was the approaches to learning of introductory problem-based learning physics students', and the relationship between those approaches and their actions within the problem-based environment. My conceptions of those phenomena were not a focus of this research study. Marton (1994 p. 427) states "as phenomenography is empirical research, the researcher (interviewer) is not studying his or her own awareness and reflection, but that of the subjects". Therefore, I attempted, as much as possible, to act as a 'neutral foil' for the opinions and approaches expressed by the participants.

An ethics statement and a subsequent letter of consent were presented to all the participants in this research (ethics statement and letter of consent can be found in Appendix F). Evans & Jabucek's (1996) view informed considered consent as the key issue in research with humans, particularly in an educational sense. Therefore, the ethics statement briefly outlines the nature, scope and purpose of the project and also indicates that all data gathered will be treated confidentially and students are under no obligation to participate. It also includes a statement that each participant is free to withdraw consent and discontinue participation in the research at any time without prejudice. All participants are offered the opportunity to remain anonymous when the outcomes of the research are published.

4.8 Chapter Summary

This chapter has situated this study in the context of interpretivism due to its focus on students' experience, approach and understanding. The theoretical assumptions were discussed and justified and the research was firmly placed within the phenomenographic tradition. The methods associated with a phenomenographic approach as the methodology were adopted to carry out this research and answer the research questions. Through analysis of the data obtained from these methods and by comparing the resulting categories and outcome spaces and seeking relationships between the other methods employed, it was possible to answer the following research questions:

- What are the qualitatively different ways in which students approach their learning in the context of problem based learning?
- What are the qualitatively different ways a student perceives the problem-based learning environment?
- How do students approaches manifest as actions in a problem-based learning environment?
- What gain in conceptual mechanics physics knowledge do individual students achieve in a problem based learning course?
- What is the relationship between students approaches to learning, their assessment scores and the actions that manifest during problem based learning?

The following six chapters contain the findings from this research study and within these chapters the findings are discussed and the research questions outlined above are answered.

CHAPTER 5

REVIEW OF FINDINGS – APPROACHES TO LEARNING

5.1 Introduction to chapter

The previous chapter described the methodology and methods used in this study to obtain the data needed to begin answering the research questions. The following chapter is split into four sections of investigation and aims to present the research in three capacities. The first is the approaches to learning and variations in the perception of the problem-based learning environment. The second is to attribute to each student an approach and perception and to correlate this with their results on the FMCE and other graded material related to their performance in the course that they had undertaken. The third capacity is to examine both solely and in reference to each other, each result of the study and discuss in detail their relationship to this study and relevant studies from the literature pertaining to this area of educational research.

In the following chapters (Chapters 5-9) the findings from the analysis of the data are presented separately in each chapter and are then related to individual students. Then the relationship between the findings and the literature on this particular area of research is discussed in detail. Finally (Chapter 10) the relationship between results is discussed in its own right and then again in relation to past literature on the subject. So, for example, the perceptions of the learning environment are presented as findings. Then the individual students are grouped into the categories of perception and presented. The categories of perception are discussed in relation to previous research on perceptions of learning and problem-based learning environments. Finally, the categories of perception are discussed in relation to the findings in the previous chapters on approaches to learning in a problem-based learning environment and how the literature has portrayed this relationship in the past.

5.2 Approaches to learning in the problem-based learning environment

5.2.1 Introduction to approaches to learning in the problem-based learning environment

This section is the first of two which presents and discusses the findings from the analysis of the phenomenographic interviews that were conducted for this study in an attempt to answer the following research questions:

- What are the variations in students' *approaches* to their learning in the problem-based learning environment?
- What are the variations in students' *perceptions* of the problem-based learning environment?

This section aims to answer the first question and as it is the first to discuss the phenomenographic interviews, I will take this opportunity to explain in detail the process of analysis which was carried out in order to constitute the categories of description, focusing specifically on variation in approaches to learning in the problem-based learning environment as the object of analysis. The findings from this analysis are then presented as categories, followed by a discussion of the structure of the categories and the section concludes with a discussion of these findings with respect to relevant literature in the area.

5.2.2 Interview data analysis process

The transcripts taken from the video interviews were analysed in a method that I would broadly describe as several iterative processes. Each transcript was read and reread repeatedly, often in one sitting, in order to become acquainted with the transcript set as a whole. For each sitting of a reading I endeavoured to focus my awareness on one particular aspect of the transcripts. For example, on one occasion I may have focused on how the students described their approach to the first problem-based learning session, on another occasion I might pay careful attention to aspects of the problems that the students focused on and on yet another occasion, I would have focussed on students' conceptions of understanding. As discussed in section 3.1, students conceptions of what it means to them to understand something in physics has been linked to students approach to learning. It became a line of questioning and a focus in this study after the first round of pilot interviews when students talked frequently of understanding but talked about understanding in diverse ways. It became clear from these pilot interviews that it would be necessary to discover students conceptions of understanding in order to discover the variation in meaning and also fully understand the connection to their approaches to learning.

After I felt that I had a sufficient amount of familiarity with the data, the next step was to make a set of notes that recorded all information that I perceived to be critical to the students' approaches to their learning in the problem-based learning environment. These notes where produced in the form of spider diagrams with each body of the spider focusing on a particular critical aspect of a student's approach to learning in the problem-based learning environment, (For example see Appendix G). This stage of the analysis resulted in several pages of notes on each of the 20 students. Once the notes had been completed I then started to seek out what I felt were the critical similarities and differences between the notes. However, my focus was not solely on the notes and instead I found myself working concurrently with the notes and transcripts as the notes often lacked the depth of completeness that the transcripts contained.

I started adding pages to the notes that had been constructed, on which I recorded cases of agreement and variation of what I discerned as critical aspects within the transcript pertaining to the approach to the learning in the problem-based learning environment. The next step was to physically group together the transcripts and corresponding notes that I perceived to have critical agreement. This initial attempt at grouping proved to be very difficult as I could often make arguments for transcripts to be placed in one of two groups. This highlighted to me that I was discerning that critical variation was occurring within some of the transcripts themselves. This perceived critical variation within the pool of meaning merely highlights the cases of variation and agreement by the need to constantly re-structure the physical position of the data. There was a temptation to assign similarities between statements that were simply the same, which often occurred due to the communal nature of problem-based learning, but that in itself was reason not to. Due to the shared experience of solving these problem-based problems together, students often expressed themselves in similar ways but these similarities are superficial and lack any depth of meaning. This assertion came from my experiences in the problem-based environment and the pilot interviews in which students talked about understanding frequently due to the emphasis the tutors put on it (a superficial similarity) but obviously had different connotations of what to them understanding meant and required.

Even without these occurrences it was obvious that it was necessary to explore the meaning, and not just the words, of what an individual was saying. The notes could sometimes illustrate agreements and variations but often did not present the meaning associated with these illustrations. This, more often than not, resulted in returning to the transcripts and exploring the pages before and after these illustrations of agreement and variation in order to discover the underlying meaning and intentions behind the approaches. I then used an excel sheet to keep track of the similarities and differences between transcripts and the notes and began to express these similarities and differences using descriptions. At this point in the research the emphasis was on discovering and describing the meaning of the categories as opposed to an exploration of the overall structure of the categories. By this I mean I was avoiding any attempt to relate the categories together and instead focused on the similarities and differences and searched for aspects of critical variation and themes within these.

The constitution of these descriptions involved constant reference to the transcripts to ensure that the descriptions accurately represented the data, while at all times focusing my attention on the fact that I was analysing the data in order to discover variations in the ways that these students approached their learning in a problem-based learning environment. This focus of my attention was important as the transcripts and interviews themselves contained much more information than that pertaining to the participants' approaches to learning. It was important not to get sidetracked, especially as it was my intention to search the same transcripts for variations in students' perceptions of the problem-based learning environment at a later stage.

This was the point at which I began to constitute the categories, by describing the critical aspects of approaches which were present in some of the transcripts and not in others and also within individual transcripts. Once tentative categories had been constituted I then began to examine the categories and the transcripts for the structure of the categories, although the structure became more evident through constant re-examination. In searching for the structural aspects of the approaches I endeavoured to identify what was focused upon within each overall meaning. In other words, I searched for themes of expanding awareness (see section 4.5.2) that were present in each preliminary category, although at different levels which served to distinguish between the categories and further identified the hierarchical structure.

For each category that I had constituted, I then went back to the groupings of transcripts and notes to find cases of both agreement and contrast within the transcripts. This was to ensure that the categories actually did describe the variations in the approaches to learning in the problem-based learning environment of this set of students faithfully and empirically. Indeed even at this stage a number of the categories had to be reconstituted and redefined, until I was satisfied that I had a set of internally related categories that holistically represented the variations in these students' approaches to problem solving.

I then shifted the unit of my analysis from approaches to the variations in these students' perceptions of the learning environment as I wanted to examine the 'why' (i.e. why students' approach their learning in this way). I carried out the analysis in exactly the same way as described previously, and although I was now familiar with the transcripts, I basically had to hit the reset button and begin analysing the transcripts with a new set of foci. Surprisingly, they did appear as different transcripts which indicated to me that by focusing only on those areas of the transcripts which were critical to the variations in approaches, I had been faithful to the data in my previous analysis. Therefore, even though I had read the transcripts many times, it required just as many iterations to arrive at a set of internally related categories describing the students' perceptions of the problem-based learning environment.

The final stage of the analysis process was to choose excerpts and statements from the transcripts which I felt would give substance and support to the categories. The process of analysing and constituting the categories of description of these students' approaches to their learning in the problem-based learning environment and variations in their perception of the learning environment took place over approximately seven months, often with rather substantial breaks in between. At times these breaks were forced, due to other work constraints. However, at other times the breaks were an intentional respite from the analysis especially when it came to a shift in focus from approaches to perceptions. I found this helpful as it often resulted in coming back to the data with a new perspective and a fresh outlook.

5.2.3 Qualitative evaluation of approaches to problem-based learning environment

5.2.3.1 Context of interview data

As discussed in Chapter 2 and again in section 4.6 where the participants are described, the problem-based learning environment in which this study took place was constructively aligned so that it would encourage and reward students to take a deep approach to their learning. Therefore, the primary aim of the interviews that were carried out, was to explore the variations in the participating students' approaches to their learning in the context of this constructively aligned problem-based learning environment. Due to this constructive alignment, the emphasis tutors put on understanding within problem-based learning assessments and, the already discussed student repetition of the term understanding, a section of the interview questioned students' conception of understanding. Another point of discussion that needs to be presented at this point is that the majority of students entering into this environment have come from the background of the Leaving Certificate which is a learning environment that focuses on rewarding a surface approach to learning (as discussed in section 1.3.1 and evidenced in physics by Walsh (2009))

Under these circumstances, students entering into a constructively aligned deep learning environment may struggle with the concept of what it means to take a deep approach. Secondary aims, such as discovering students' perceptions of their learning environment including their opinions, perceptions and approaches to their exams, were explored in other sections of the interview with the purpose of using this data to understand the reasoning behind students' approaches to their learning in the problem-based learning environment. It is worth noting at this point that at the stage the interviews were being analysed I was aware, although not acutely, of the students' respective scores on the FMCE. I took steps, both practically in the form of having the students' names coded by a colleague so I would not know which transcript referred to which student and mentally in the form of analysing these transcripts with an open mind and bracketing my knowledge of those previous results. The analysis of the interviews revealed the critical variations in students' approaches to their learning in the problem-based learning environment and these are presented as categories of description and discussed below.

As discussed in Chapter 4, the twenty first-year students who were interviewed were those who were in groups recorded by video tape which in turn were picked with some input from the CLASS questionnaires and FMCE pre results. The range of profiles of the students who participated in these interviews will be examined more deeply later in Chapter 9.

5.2.3.2 Categories of description

The analysis of the interview transcripts revealed the following set of categories that describes the variations in the interview participants' approaches to their learning in a problem-based learning environment:

- Problem-Based Learning Surface (*PBL surface*)
- Problem-Based Learning Strategic (*PBL strategic*)
- Problem-Based Learning Deep (*PBL deep*)

Firstly it is worth noting that as will be explained later in section 5.2.6.1 these categories do not necessarily or fully correspond to the deep, surface and strategic approaches reported in literature. The categories are all internally related and are described using three components; how do these students approach problem solving (characteristics), what is the intention behind their approach and what their conception of understanding is which are the themes of expanding awareness for these categories. Each category is then described in some detail, with excerpts from the interview transcripts chosen to support and give substance to the categories. During the discussion of the categories, I refer to myself (sole interviewer) as interviewer, as this is the format I used in transcribing the interviews. Table 5.1 outlines the categories and the characteristic of the themes of expanding awareness in each category.

Table 5.1 Themes of expanding awareness for approaches to learning in problem-based learning environment

Themes of Expanding Awareness	***PBL Surface Approach***	***PBL Strategic Approach***	***PBL Deep Approach***
Characteristics of approach	Asking unsophisticated questions/ working on learning issues/looking for right equation	Looking for right equation/discussion and explanations if lead to solution	Focus on discussing, explaining and reflection on others explanations
Priority of approach (intention)	To do what is expected	To get solution	To develop understanding
Conception of understanding	To be able to explain understanding to others/remember	To be able to use understanding/use to answer questions/use to explain/use in different problems and situations	To be able to explain/to understand interconnections between concepts and how they relate to each other

As per the phenomenographic methodology outlined in Chapter 4 and the analysis as explained in section 5.2.2 above, during the analysis of the interview data, I endeavoured to simultaneously constitute the meaning and structure of the categories of description. The meanings of the categories were discovered through immersion in the data and based solely on the empirical evidence within the transcripts, whereas the structure of the categories was constituted through the empirical evidence of logical inclusiveness and dimensions of variation. Therefore, themes of expanding awareness were discovered which served to distinguish the logical structure and highlight the inclusive hierarchy of the categories. The hierarchy within the three distinct categories describing the variation in these students' approaches to their learning within a problem-based learning environment is illustrated below using empirical evidence. The logical evidence for the hierarchy is presented in Table 5.1 as the themes of expanding awareness and the corresponding aspects in each category which link and distinguish one category from the other. The criterion for these themes was that they were present in each category, in a manner which highlighted the increasing level of awareness yet also served to distinguish each category from each other in a critical manner.

The variation in students' conception of understanding is present in each category and highlights the increasing level of sophistication of each category and also distinguishes each category from each other in a critical manner hence it being a theme of expanding awareness. In certain cases, the categories may have common threads, yet this serves to further define and relate the categories in terms of the variation in the approaches. An example of this can be seen between all three of the categories in the case of students having a similar awareness of one element of their conception of understanding. That is being able to explain a concept to someone else. However, each category's awareness of their perception of understanding composites more elements than this and it is the variations such as this that marks these concepts as significantly individual in respect to each other.

5.2.3.3 PBL Surface Approach

The *PBL surface* approach has elements of the traditional surface approach but is inherently more confused in nature, with students who adopted this approach describing characteristics found in the *PBL strategic* but with a less sophisticated conception of understanding than both the *PBL strategic* and *PBL deep*. The approach also has mixed priorities as students' intentions are both to understand and solve the problem. This combination of the intention behind the *PBL deep* and *PBL strategic* results in a priority of doing what is expected. *PBL surface* students are aware that the learning environment is encouraging them to understand but they are also motivated by the need to find a solution. Most importantly even if they had the sole intention of understanding they do not have a sophisticated enough conception of understanding to do so.

In relation to characteristics, the method of problem-solving for a student who has a *PBL surface* to their learning in problem-based learning is to try to seek an equation that relates the variables in the problem together to produce and answer or use an example from a book that displays a worked out example of a similar scenario:

Interviewer: *What would the working out process involve?*

Student G: *Putting all the equations together and going step by step through every single part. And you normally then had the knowledge of what it was all about and you were just putting everything into the equations and following it through and putting 2 equations together to get your real equation or whatever.*

Or in a similar manner:

Student R: *I do my learning issues and then and sometimes try and eh, If I can find similar problems to see could I, you know, compare the two.*

Students adopting this approach also described putting in a lot of effort in-between classes often making reference to "learning issues" as a major aspect of their contribution and their ability to contribute. The time spent would be indicative of their priority to do what is expected as tutors expect learning issues to be done between class.

Student H: *A lot of times I would have done a lot of work and I would have come in and been a bit more cocky if I knew something and I wanted to get it out there, I wanted people to know that I knew it.*

Again because of this priority of doing what is expected they will spend the majority of the first session asking questions and often see it as their only method of contribution in the first session. However although question asking would be a positive contribution to a problem-based learning session these questions are again limited by the students conception of understanding.

Interviewer: *Ok so do you think you had a specific role in any of your groups?*

Student A: *In the first group I was in, I was just, I just asked questions that's all I did because everyone else like took it that everyone knew what was going on so I just kept on asking questions.*

After obtaining the learning issues at the end of the first session they will research and then come into the next session and explain their understanding of said learning issues. But again the sophistication of explanations is limited by the students conception of understanding and so will be verbatim definitions and problem solutions from the books they have read.

Student R: *Then your doing learning issues but you don't know what you're doing them for em whereas on the Thursday if you've done the learning issues you can eh, you can feel a lot more confident and you can say you know put forward your planned ideas and things like that.*

These students make no reference to explaining their ideas or disagreement over understanding with fellow students outside the realm of learning issues. There is no evidence of students engaging in cognitive conflict in order to test their understanding. But they did ask questions for understanding, research to understand and to explain their understanding which are all positive contributions to the process. All students exhibited an intention to understand but all were limited by adopting an unsophisticated approach to conceptions on understanding. The solution though is important to these students too, or, at least, it is at the beginning of the course as the following quote indicates:

Interviewer: *So at the end of the first one, what was it the group, or the group of individuals as you put it, what do you think you were trying to accomplish by the end of that session?*

Student H: *Well for the first few weeks we always saw it as we have to solve this question, this question has to be done. After about 2 or 3 weeks we realised it wasn't the question that puzzled us, it was what the question was representing. That puzzled us, it was what was behind it, it was mechanics so you were looking at a lot of physical elements behind it that we needed to know. And then we realised that answering the question, that wasn't the end, there was no end, we had to try and understand too.*

Unlike the *PBL strategic,* students adopting the *PBL surface* make no reference to annoyance over time wasting or solving the problem as quickly as possible. In many ways this mixed message of solution and understanding to the focus of their awareness may be counterproductive and an indication of a changing approach by students due to the confrontation with a new active learning environment.

Students with *PBL surface* conception of understanding is unsophisticated in that these students see it as the ability to explain a concept to another individual and them understanding it in turn.

Interviewer: *To you what does it mean to understand something?*

Student A: *To be able to re-explain. To be able to explain to someone else then you've obviously understood it if you can explain it.*

Although a conception of understanding that posits being able to explain something as understanding is not necessarily unsophisticated, it is the memory aspect of their awareness when it comes to understanding, that informs the type of explanations students adopting this approach may give:

Interviewer: *If you understand something what does that mean?*

Student F: *That you'll, I dunno that, you'll never forget it, I dunno em, that you can if you understand something like I've said it before you'll be able to explain it but again you'll never forget it like you're kind of always remembering*

Interviewer: *Ok*

Student F: *If you understand how something works you never – if you really understand how something works you're never like not remember how it works.*

In summation, students adopting the *PBL surface approach* seek both a solution and understanding but the understanding that the students adopting this approach seek is limited by their own conception of what it means to understand a concept. For the most part though, their priority is to do as expected. This is evidenced by their emphasis on learning issues and an intention of understanding without any real conception of what that means or why they are seeking it.

5.2.3.4 PBL Strategic Approach

The *PBL strategic approach* is centred around the students focusing all their attention on finding a solution to the problem-based learning problem. Their emphasis on focusing on solving the problem results in every aspect of their awareness being informed by this goal. So students taking this approach describe characteristics that indicate a solution driven approach and depict an intention to solve the problem. Students adopting this approach also have a conception of understanding that relates to this focus on solving the problem. Their descriptions of what it means to understand a concept is based firmly in the realm of application. That to understand something is to be able to use the information again, possibly in different situations or to either explain to or answer the queries of others in relation to a concept. In addition, their explanations of concepts will not be reproductive in nature rather they are based around how concepts apply and can be used in situations.

These students are often aware that the learning environment encourages understanding but choose not to approach the learning environment in that capacity.

Interviewer: *What was it that you were trying to accomplish by the end of the second day?*

Student B: *The solution.*

Interviewer: *The solution?*

Student B: *Cause I was being graded on it. That's all I thought of was the solution cause I was being graded on it*

Interviewer: *Ok*

Student B: *Yeah. Ideally I'd be bringing my own understanding, but I would always end up feeling pissed off by it. I'd always end up, I just don't care anymore. I'd say fuck it all, I've had enough, do the solution, get rid of it.*

It is interesting that the student points to the solution as being what they are being graded on as later when asked what the tutor expects from you in problem-based learning the same student answers:

Student B: *A better understanding. That's the whole point of PBL isn't it? To get a better understanding of what your doing*

This indicates that while they are aware that they should be trying to understand and that sometimes they will attempt this, their focus is still on the solution. Students adopting this approach to their learning in the problem-based learning environment can be characterised by the way they focus their attentions to finding formulae or examples of similar problems which will produce a method that will result in an answer. This is a characteristic that this approach shares with the *PBL strategic approach*.

Interviewer: *You'd be given the problem, what would be the first thing that you would do?*

Student J: *Kind of look at what the main idea of it is and break it into parts usually and see, like, what parts I know already and see if I can relate that to and then try and find out what bits of information are completely irrelevant as well, cause we got some of that as well, eh and then usually everything's based on what you're doing that week so it's like if I go to the tutorial and I'm studying electromagnetism it's going to be on electromagnetism*

Interviewer: *Right*

Student J: *So open up the book and look for the formula's that relate to it (laughs)*

But this approach is not defined by this alone and encompasses some of the key aspects of types of participation that would be expected from students in a problem-based learning environment such as explaining ones understanding or discussing when their opinion conflicts with other group members and contributing ideas to the process:

Student T: *Well the last time I did resistance, so I stood up and I presented resistance to the group. So I made sure that everybody knew what it was and if another member of the group was doing current, they would make sure that everyone knew what current was. So once we knew everything, we had a plan, we filled in all the formulas and all the facts we had and we solved the problem.*

Although these are positive contributions in a problem-based learning environment and, if undertaken, would aid in the individuals understanding, they must be discussed in the context of the students intentions. As can be seen from the extracts, these students see explaining almost as a step towards the solution. The intention of those approaching their learning in the problem-based learning environment using this approach is to get the solution or finding what they need to know. Students adopting this approach will often indicate that speed of solution is important to them and that they consider a problem-based learning problem to be finished when they have obtained the answer.

Interviewer: *What was your role in the actual calculation of a solution?*

Student L: *It would be...I like to get to the solution of the problem fast and it is good to get into it and get it done fast without wondering about other things for too* *long because at least if you tried to do it one way then if it goes wrong I would find out that it was wrong. So then I'd try to get the solution, once you are sure it is the right solution it is no problem, just take it like that.*

The next extract displays speed in another manner in that the students adopting this approach will often see listening to others ideas and explanations as being surplus to their requirement of solving the problem and therefore unnecessary:

Student P: *You do listen to other people's ideas but when someone says something you know is wrong, it is hard to wait for them to continue to say their idea without going actually that doesn't make sense because of this. It's not that frustrating, it is slightly frustrating.*

Since speed and solution are motivators to those taking up this approach, students often describe a key facet of their approach as to finding the right equation that will work to give a solution to the problem or finding the right example that they can transfer a similar method to the problem. This of its nature is a strategic approach although it would be expected that the intention behind it would be to get good marks. However, in the problem-based learning environment, it becomes distorted from the traditional conception of a strategic approach. Instead and, quite unique to traditional conceptions of strategic approaches to learning, the intention is solely to get a solution to the problem as has been indicated by several of the above extracts.

However, even with this intention of getting a solution, students adopting this approach often come to the realisation that they must understand a concept in order to get to a solution and so they will attempt to understand. It is this awareness and ability to choose to attempt to understand that makes this approach strategic and different from the surface approach. More importantly it is the *PBL strategic approach* concept of understanding that enables students to engage in trying to understand the material. In the following excerpt a student discusses the relationship between understanding and obtaining a solution:

Interviewer: *You were given the problem on Tuesday. Em, describe what you would do from that point on, when you were given the problem*

Student I: *When I was given the problem, I would spend the day, well during that time,, trying to understand what the problem is. Get a picture of it, what is going on in PBL. If we in PBL, if we're working in groups we're trying to get the idea, 'what the hell is the problem trying to tell us' and then, not solving the problem, we get to that later on. Solving, once you get the idea and you get what the problem is trying to tell you, what the question is trying to tell you it's easier to solve. So then in PBL if I get, so for me I would try and get what is the question trying to tell you and then you just list out all the question. Because I was doing that, I was trying to get the solution straight away. A whole semester of trying to get into the solution straight away and you, once it gets difficult, you can't get the solution straight away because if you get the solution straight away its just making a really big mess. So you're trying to em, understand what the question is trying to tell you and then after that you get to solve it.*

The above excerpts demonstrate that the student identifies that they can't just try and solve the problem-based learning problem with the intention they normally would and he comes to the realisation that they must obtain some understanding before a solution can be arrived at but still the solution is the focus of the endeavour of getting an understanding. As mentioned above, a student's conception of understanding whose approach is the strategic approach is based firmly around application. Students describe being able to employ concepts in different situations and the ability to answer questions in relation to a concept is to have an understanding:

Interviewer: *What does it mean to understand something?*

Student B: *A better understanding of what you're doing instead of sitting back and learning all the stuff told to you. You don't even understand it and later on you could use it but maybe not understand it and could probably do research and you'd see something but you wouldn't have a clue what the hell it is or how to manipulate it. How to use it. You'd know the formula of it or something but you wouldn't know how to apply it to something like that, you know?*

Or

Interviewer: *What does it mean to understand something?*

Student S: *Mmm...I suppose if you were given a question and you were able to do it because you understand it and you'd know other examples. Like from your knowledge of physics you'd be able to solve the problem because you understand what you have been taught.*

This conception of understanding has obviously more sophisticated elements than that of the *PBL surface* approach as the extracts indicate that remembering and explaining is not enough. Instead this conception is firmly based in use of understanding to solve problems even in different contexts. In summation the *PBL strategic* approach is based around an intention to solve the problem which is unique to previous interpretations of strategic approaches and this intention informs on how students contribute in the problem-based learning sessions. This intention may very well be a result of the students conception of understanding as they see understanding as usage. Students adopting the strategic approach will seek the fastest possible resolution to the problem so if they can solve it without having to understand the conceptual underpinnings of it they will do so but if understanding is needed in order to solve the problem these students will undertake that task as well and more importantly have the more sophisticated conception of understanding to do so. Students taking this approach will participate in ways that are both conducive to the group and their individual understanding but without the firm intention of gaining an understanding or working well in a group.

5.2.3.5 PBL Deep Approach

Students adopting the *PBL deep* approach to their learning make certain to match the assessment scheme and their need to understand their own individual goals and so focus on approaching their learning with the goal of achieving the assessment outcomes of the course and understanding physics. So since the course is designed to be an active learning environment where learning and understanding come from discussing and explaining within the group and it is designed so that you take a deep approach to your learning, they too in turn take a deep approach to their learning as long as they feel it meets their own goals within the learning environment. Students taking this approach are not looking for a solution, they are looking for meaning and understanding. They also have a more sophisticated conception of what understanding is, with the belief that it is not just understanding the concept itself but also the interrelationships between concepts and the facets that make up a concept.

So students who adopt this approach have a very complete view of what is expected of them in this learning environment and, in turn, this matches the characteristics that describe their approach. The following excerpt is a description of what participating using this approach encompasses in one of the problem-based learning sessions:

Interviewer: *So the second day, the Thursday, could you describe for me what you would do in that session?*

Student N: *Well I would try and see what everybody else in the group found out. Like the last problem we did, I felt I had a good understanding of it and I felt I had learned enough to be able to solve it but I didn't want to just run in there and say, oh I think I have the solution. I had to try and ask the group, what did ye find out. And they'd say what they found out. And I would try and explain what I found out but I would try and explain what I found out and how I think this applies to the solution, I wouldn't just ram the solution down their throat. I think I tried that once or twice and it just doesn't work. It is easier to explain what you have learned although that can be difficult sometimes as well, just trying to explain your ideas as well. But generally I would try and just explain what I have learned but I would try and find out what other people had learned as well but I don't want to jump the gun because maybe somebody else has figured it out before I have. I am not the only one who has been looking at the problem. But I would talk to the other people first.*

Interviewer: *Ok so there is an information share there, what is the next thing that happens?*

Student N: *Well generally you might think that you have learned everything there is to know about the problem but someone else will come along and find an even easier way to do it so that is why it is best to get other people's ideas as well. But generally once we have taken everybody's information and we thing we have the most logical solution or way of looking at the problem, we will try and attack it that way and try and draw up a plan then. Once we feel that everybody has a good understanding and that generally depends on the people that are there. If somebody doesn't understand it and they don't ask, then you won't go into it, but generally it is good to have somebody there who doesn't understand it in the group because then you are forced to explain your ideas and why you think it works and why it doesn't work. But generally yeah we would try and just lay out a plan to try and solve it. We have a couple of times tried to launch, just doing the solution and that but it just doesn't work.*

Or

Student D: *I remember at the start, the mechanics ones, I was definitely talking a lot about, like trying to explain things as best as I could and listening to other people and trying to get them to understand stuff.*

As the above excerpt displays students who take this approach to their learning, focus on making sure the group functions as it should. So they explain ideas but also take others on board as well. They solve but don't just give the other students the solution and say that's it. They focus on making sure all of the students have the same level of understanding of the topic and encourage questions that may slow down the process of getting the solution as they force their group members to confront your own understanding of the ideas and concepts. They also encourage other students to explain their ideas as they viewed these as valuable contributions to both the solution and obtaining understanding.

Student E: *Because we frequently came back with answers that were clearly quotes from books and only half understood as well so I ended up talking and getting the others to explain what things in the book actually meant, what we had looked up, what the significance was. We frequently tried to understand it, not just be able to repeat it but to fundamentally understand the physics behind it.*

Like the *PBL strategic* approach, students who adopt this approach will explain to others what they understand but the difference is that these students conception of understanding is much more sophisticated. As a result, their explanations will not just be the presentation of the usage of a concept or knowledge but instead will be how the concepts link with the scenario in the problem and with other concepts and the individual facets that make up the concept.

Students adopting this approach will also have a tendency to lead their group but again like the *PBL strategic* approach indicated above, this leading or focusing is related to the intentions of the students adopting this approach. Since students adopting this approach intend to understand the course material, they will lead and focus their groups on understanding. They still value getting a solution but not as much as in the previous two approaches.

Student E: *I read that PBL had previously been organised with a leader or a project manager, I don't know what the person was called but a chair basically and that their job was to keep control and keep everyone focused and to draw out ideas and so on. So when I read that I assumed that role for the next problem and it was effective so I suggested this is what we do each time.*

So the intention of students adopting this approach is without doubt to understand the physics that they are learning in the problem-based learning environment:

Student E: *I thought that there were things that I understood and I realised as soon as I was presented with concepts without the benefit of words for specific concepts, I realised that I didn't have a clue how these things worked. So I think that was one of the things that I did well. When I didn't understand something I got others to explain in a way that I could understand or I went and found out about it myself.*

Like the *PBL strategic,* this *PBL deep* approach differs from the classical description of a deep approach to learning and this may be because it is based in a learning environment in which a deep approach to learning is encouraged. Students adopting this approach are aware of what the learning environment is trying to encourage and are distinctly aware of the assessment criteria and will not go outside of that purview even if it is to mean getting a greater understanding of a concept.

Student E: *And I knew as well as I was learning each module that it was modular, you could spend an awful lot of time just trying to understand something that you weren't really going to understand until you looked over other stuff. So it was difficult to keep things in perspective but yeah, I was satisfied with understanding enough to answer the question as long as I understood everything that I needed to understand.*

So students adopting this approach are aware that there is linkage between modules and that a complete understanding may not occur unless they link the concepts they learn in problem-based learning to the concepts they learn in other modules. The classical deep approach describes an inherent interest in the subject and intrinsic motivation which implies no awareness of assessment. The *PBL deep* students do have an intrinsic motivation and an inherent interest but it is tempered by awareness of the reality of a problem-based environment, assessment and their own personal learning goals. As opposed to the other approaches, the *PBL deep* approach differs in its conception of understanding, viewing its purpose as being to know everything about a concept at its fundamental level and to be able to relate every facet of a concept to each other and apply this information in any context. This interrelationship of the facets that make a concept is what makes this approach unique to the others discussed above.

Student E: *To understand something is to be able to model it mentally or... yeah well to be able to either model something mentally as in visualise it or to know how a concept is related to something or related to it. This is really vague. Like if there is an issue that is related to other things, knowing how it is related to those things is to understand the issue, is understanding the issue.*

Or

Student N: *If you have learned something then it means that you understand the connections between it and other things that you understand*

Students adopting this approach wish to gain an understanding within the boundaries of the learning environment and aim to do so by contributing within the learning environment in the way in which the assessment scheme has indicated. They also assume that understanding and learning will occur by achieving these goals and their own personal goals.

5.2.4 Summary

The categories referred to in this chapter were constituted from all of the data from the interview transcripts and, therefore, the categories represent the 'collective mind' of the students who were interviewed. No single category can be assigned to any one student according to the phenomenographic approach. For example, a *PBL deep* approach to learning in problem-based learning, could in fact theoretically incorporate a *PBL strategic* approach. However, traditionally and within this study, intent is attributed to the constructs of approaches to learning. For the intention to change within the approach, something in the learning environment must influence this change. For example, students adopting the *PBL deep* approach could choose to slip into the *PBL strategic* approach. This would result in them ignoring the assessment scheme for the course and their intrinsic interest in understanding and instead focusing on solving the problem. This choice could be a result of the students perceiving a time constraint on solving the problem. But in the reality of approaches to learning, switches like the one just described would be unlikely as is indicated in the approaches learning sections of the literature review. However, this adaptation by the students with the *PBL deep* approach would not be possible in reverse, i.e. a *PBL strategic* student would not be able to adopt a *PBL deep* approach as it would involve the *PBL strategic* student evolving to a higher level of awareness and sophistication in their conception of understanding. This is not to say this evolution and sophistication is not possible, in fact in the problem-based learning course it would be encouraged. This change however, requires an evolution in fundamental aspects of the approach whereas a *PBL deep* student choosing a *PBL strategic* approach just involves a deliberate choice to ignore the assessment outcome of understanding and instead focusing on solving the problem.

As can be seen, the themes of expanding awareness illustrate the shift from the first category (*PBL surface*) to the third category (*PBL deep*), from a solution/understanding approach limited by a poor conception of understanding to a pure understanding approach that has a very evolved conception of what it means to understand a concept. In the following section, the students that took part in the research are placed into the approaches to learning in problem-based learning categories. This may seem to be contradictory to what has been indicated in the above summary. However, the process will be explained in detail below.

5.2.5 Putting students into categories

At this point, I leave the phenomenographic methodology behind because as stated previously, during the analysis of the transcripts the categories were constituted from all of the data from the interviews and no one student can necessarily be described by a single category. However, once analysis was complete and the stable categories were constituted, I felt it was possible, for illustrative purposes, to place individual transcripts within the category with which they most identified, in regard to their approach to learning in the problem-based learning environment. After examining the categories of description after their constitution and after rereading and evaluating the transcripts, I found it possible to place the transcripts in a respective category based on themes of expanding awareness exhibited by the respective transcripts. The table below presents the students' code names and their associated approach to learning in the problem-based learning environment.

Table 5.2 Students placed in approaches to learning categories

Approach to learning	Students associated with approach
PBL Deep	*Student E* *Student N*
PBL Strategic	*Student B* *Student C* *Student D* *Student I* *Student J* *Student L* *Student M* *Student O* *Student P* *Student Q*
PBL Surface	*Student A* *Student F* *Student G* *Student H* *Student K* *Student R* ` *Student S* *Student T*

Table 5.2 above illustrates the approaches to learning that I perceived each individual student to have taken from their interview manuscripts. The next chapter discusses perceptions of the learning environment. After the various perceptions of the learning environment have been presented, the transcripts were then assessed to discover which perception it matched using the same method outlined above and then these results are discussed in relation to each other in section 6.5.

5.2.6 Discussion of approaches to problem-based learning environment categories

The following sections will discuss the findings presented above in relation to three topics:

Comparisons between previous approaches to learning categories and the categories presented above.

Comparisons between the Ellis *et al.* 2007 study, Duke *et al.* 1998 study of approaches to learning in a problem-based learning environment and the categories presented above.

The relationship between conception of understanding and previous research on meta-learning and comparison to other conceptions of understanding research.

5.2.6.1 Comparisons between previous approaches to learning categories and the categories presented above.

The most significant result of the approaches to learning categories discovered in this study, is the essential part that students conceptions of understanding plays in their approach. As indicated in the literature review in sections 2.3 and 3.2, students conceptions of understanding have been linked to their approaches to learning (Perry 1970; Saljo 1979 & Marton, 1988). If you examine sections 2.3.3 and 2.3.4 of the literature review that describe the traditional approaches to learning, you will not find descriptions of students conception of understanding. The results from this study show that in an active learning environment that is constructively aligned so that students develop a conceptual understanding of physics, students conceptions of understanding are intrinsic to the approach they adopt to the learning environment. In many ways, the students conception of understanding is the most influential of the themes of expanding awareness discovered because, as discussed previously, the *PBL surface* approach may have the intention to understand but the students do not have a sophisticated concept of what it means to develop an understanding of physics to actually do so. It is the conception of understanding that overrules the deep intention and results in a surface approach. So firstly, the fact that conception of understanding is inherent in the each of the three approaches is what marks them apart from traditional approaches to learning. Whether the conceptions are unique to this learning environment will be discussed in section 6.3.

With this in mind and starting with the *PBL deep* approach, it is apparent that conception of understanding of the approach also informs the strategy students employ in the learning environment. For example, the *PBL deep* students describe explaining and arguing points and asking questions but then comparatively the *PBL surface* employs some of the same methods. The difference is in the level of sophistication of the questions and descriptions and the level reached by the approach is limited by the approaches respective conceptions of understanding. Given this significant difference and examining the three approaches again, it is apparent that the *PBL deep* approach is the one that is most easy to relate to the previous traditional approaches. The majority of research studies from Marton & Saljo (1976a, 1976b) to Baeten *et al.* (2008) that have investigated approaches to learning have found the presence of and described a deep approach to learning and this approach has always included many of the same elements. As Baeten *et al.* (2008) indicates, students who are taking a deep approach are characterised by the intention to understand and extract meaning from the content to be learned and they have a preference for a learning environment which is likely to promote understanding.

The *PBL deep* approach shares this intention to understand and a preference for the problem-based learning environment which these students perceive as promoting understanding. The similarities do not stop there, as Baeten *et al.* 2008 also indicate that the deep approach encompasses relating ideas to previous knowledge, to look for patterns, check evidence and critically examine arguments. The *PBL deep* approach includes these various elements, especially the last of critically examining arguments. If anything, this element of the description is fundamental to having a deep approach to learning in a problem-based learning environment and it is the where the emphasis of “PBL” in the name *PBL deep* comes into play and diverges from an atypical description of a deep approach to learning. The presence of other group members in the learning process introduces these new elements in the description of the *PBL deep* approach. So to have a deep approach in an active problem-based learning environment, you must discuss and explain your understanding with other group members but also listen and question the understanding of concepts by the others in the group and so critically examine the arguments of fellow group members but also be able to critically examine your own understanding of concepts in this learning environment, all of which is informed by the deep students conception of understanding. Another unique descriptor of the approach in the context of problem-based learning, is that these deep students often feel the need to lead their group and any discussion within the group.

One of the major differences between traditional deep approach to learning and the *PBL deep* approach is the lack of intrinsic interest in the subject. The *PBL deep* students make no reference to being intrinsically interested in the subject of physics but this finding is not that uncommon. Hall *et al.* (2004), Wilson & Fowler (2005), Biggs & Rihn, (1984) and Dart & Clarke (1991) have come up with similar findings of students adopting deep strategies without the intrinsic interest in the subject. It has been concluded in the past that environmental influence has more of an effect on students approach to their learning rather than motivational factors and this would seem to be the case in this study for both the *PBL deep* and *PBL surface* approaches.

Another major disparity between the *PBL deep* approach and the normal description of a deep approach to learning comes in the form of awareness. The *PBL deep* category is grounded in a heightened awareness of many elements of the learning environment and of themselves. This approach is categorised by students finding out the assessment protocols of the course and making sure to match their learning goals with those of the learning environment. This may sound like a surface approach or strategic approach to learning but I believe that this apparent similarity is only due to the learning environment itself. *PBL deep* students are aware that the problem-based learning course is designed so that they adopt a deep approach to their learning and, since this would be their approach anyway, they are merely matching their approach to the encouraged approach to do well on the assessment criteria but still have an emphasis on understanding the material. This thread of the discussion will be picked up again in the comparison between the Ellis *et al.* 2007 approaches and the approaches discovered in section 5.2.6.2.

Moving on to the *PBL strategic* approach and we find two major disparities between the traditional strategic approach and the *PBL strategic* approach. The first disparity is that like all of the approaches found in this research study, the conception of understanding is an intrinsic part of the approach and influences the strategy employed by these students which is not the case for the traditional strategic approach. The second disparity between the *PBL strategic* and the traditional description of a strategic approach is the focus on solution rather than assessment. According to Ramsden (1981) and Entwistle (1981), students adopting a strategic approach will adopt either a deep or surface approach to their learning depending on which they perceive will help them to achieve high grades. The *PBL strategic* approach will adopt either a deep or surface approach to their learning depending on which they perceive will help them to solve the problem-based learning problem as quickly as possible. Students adopting this approach will only exhibit similar strategies to those taking a deep approach when they perceive a need to fundamentally understand an aspect of the problem in order to solve it.

The argument has been made by Snyder (1971) that the strategic approach is the manifestation of the 'hidden curriculum' idea of students familiarising themselves with what the tutors expect. However, the hidden curriculum concept is much more complex in this learning environment as the description of the *PBL strategic* approach indicates that these students are often aware that the tutors expect understanding but the students still emphasise solving the problem. The complexity arises in the multiple aspects of assessment in the problem-based learning course. Although the *PBL strategic* approach may not be the result of a manifestation of tutor expectations or perceptions of tutor expectations, it is possible that it is the manifestation of their perceptions that the solution is assessed in the report which is may be more important to them than the tutor feedback assessment. It could also be true that they perceive the solution imperative to do well on the end of semester assessments. This could be indicative of a transformation of the concept of the hidden curriculum due to tutors in the learning environment no longer being perceived as the authorities with the 'correct answer' due to the student-centred learning environment. The concept of the hidden curriculum may well then become whatever the student perceives it to be, for the *PBL strategic* it is what they are familiar with from their previous learning environment: solving the problem.

The majority of descriptions of the achieving or strategic approach (Entwistle & Ramsden 1983, Watkins 2000) emphasise that a singular intention behind said approach is to maximise grades. This is not true for the *PBL strategic* approach, instead the shift in intention is towards solving the problem. However, if you examine the Kember *et al*. (1999) description of the motive behind strategic being based on competition and ego-enhancement: obtaining highest grades, whether or not material is interesting, then replacement of solution with grades may be explainable. What could be more competitive or ego-enhancing than solving a problem faster than two other groups that are working in the same room as you Re-examining Richardson's (1993) description of what a strategic approach entails, indicates how unique the *PBL strategic* approach is to this learning environment when the focus on intention shifts from assessment to solving. There are similarities though as Richardson indicates that the strategic approach involves using time and resources to greatest effect and looking for hints for assessment. These elements are transferable as *PBL strategic* students who are very aware of time and how best to use it and also look for hints from tutors for direction for solutions or to see if on the right path.

The final category discovered in this research project is the *PBL surface* approach. Again like the previous two approaches discussed, the most significant divergence from traditional surface approaches is the role that students conception of understanding plays in this approach. As mentioned previously, conception of understanding would not be in a traditional description of a surface approach to learning but, in this learning environment, it is the key fundamental influence over the *PBL surface* approach. This is because these students display a mixed intention of understanding and solving influenced by their priority to do what is expected. This intention to understand is limited by their lack of sophistication in what it means to understand in physics. Not only that but the strategies they employ from this approach of asking questions and discussing are again limited by their conception of understanding.

The following point is discussed in more detail in section 5.2.6.3 but this approach seems to identify students who previously would have had a surface approach to their learning. After a semester of learning in the problem-based learning environment, however, they have neither become meta-cognitively aware enough to realise that the learning environment is not encouraging surface learning nor are they aware that the tutors expect them to understand the material. However, this awareness is split between their intention to gain an understanding within the course and their own personal goal of solving the problem. In many ways, they are in the process of evolving their approach but are stuck at a crossroads of choice between *PBL strategic* and *PBL deep*. They understand that the course design and the tutors are pushing them towards the *PBL deep* road but are hesitant because of their previous affinity with a more tangible goal orientated approach to their learning acquired from their approach to the Leaving Certificate (Walsh 2009).

Add to this a conception of understanding that is based around being able to explain their understanding to someone else. This could be considered an admirable conception of understanding if it were not intertwined with their previous surface approach. So when they explain their understanding to another student, it is in the sense of reproducing information which is an element that Marton & Saljo (1976) attribute to having a surface approach. This mix of intentions and the inclusion of conception of understanding, distinguishes this approach from the traditional interpretations of a surface approach. The *PBL surface approach* exhibits many aspects of a typical surface approach especially in relation to the methods employed by students to solve the problem: looking for similar examples or plugging and chugging numbers (Birenbaum & Rosenau 2006; Entwistle & Ramsden 1983 and Walsh 2009).

Simplifying the approaches, it becomes clear that the approaches to learning found in this study are a complex interrelationship between priority (intention), conception of understanding and characteristics of approach. With the characteristics being a result of the priority and conception of understanding but with intention not enough to influence a change in approach without an evolution in the sophistication of the approaches conception of understanding.

5.2.6.2 Comparisons between the Ellis et al 2007 study, Duke et al 1998 study of approaches to learning in a problem-based learning environment and the categories presented above.

Considering that both the Ellis *et al.* 2007 paper and Duke *et al.* 1998 paper are both investigating approaches to learning in a problem-based learning environment, there should be significant overlap in the approaches discovered when using a similar phenomenographic approach. Although approaches are contextually dependent (Ramsden 1988) and as stated in Chapter 2, any approaches found would be dependent on the problem-based learning physics environment. Taking this into account, I would still propose that distinguishable differences in the approaches would be as a result of the different learning environments in which the studies are set in and that comparison between the approaches discovered in each study could elucidate some of the effects learning environment may have on a student's approach to learning.

Table 5.3 Comparison between this study's approaches and Ellis *et al.* (2007) approaches

Approach	Description	Approach	Description
PBL Deep	Emphasises on a need to understand the physics behind the problem and using methodologies that promote understanding while also with a firm eye on performing well in the assessment	Deep	Emphasises a need to use professional methodologies and judgement in order to fully understand the problem scenarios
PBL Strategic	Emphasises a deep or surface strategy to solving the problem (which ever appropriate) with the main intention of solving while ignoring the assessment protocols	Achieving	Emphasises a deep strategy to understand the context of a patients situation with the main intention of performing well in the assessment of the case
PBL Surface	Emphasis on gathering information and using it in a surface manner but with the intention of both solving and understanding the problem	Surface	Emphasises gathering information
		Surface	Emphasises routine work
		Surface	Emphasises a main purpose of gathering routine skills without being aware of their particular relevance to Pharmacy contexts

Taking the Ellis et al approaches first, as the Table 5.3 demonstrates, there are both significant differences and similarities between the two sets of approaches to learning. The *PBL deep* and the Ellis *et al. deep* are very similar in that both of them emphasise the use of appropriate methodologies for their respective environments. Ellis *et al.* use "professional" as their terminology for methodologies which match with the tutor expected methodologies that the *PBL deep* employs. However, there seems to be a cross pollination between the *PBL deep* and the Ellis *et al. deep* and *achieving* approaches. In the *PBL deep,* the intention is to both understand and to do well in the assessment which is a combination of Ellis *et al.*

deep and *achieving* intentions. There seems to be a correlation in that both studies contain deep and strategic/achieving approaches.

Duke *et al.* (1998) on the other hand do not seem to have a strategic approach in their learning environment, however, an area of overlap between deep approach in my study and Duke *et al*., is Duke *et al*. “approach D” deep students recognised the applicability of information to other situations which I would argue is evidence of a more sophisticated conception of understanding.

However, the *PBL strategic* and *achieving* approaches are dissimilar in both intention and strategies employed. The *PBL strategic* approach will employ either surface or deep approaches depending on which one will facilitate a solution to the problem and the approach often ignores the assessment criteria whereas the Ellis *et al. achieving* approach emphasises a deep strategy with the intention of doing well on the assessment. I believe this divergence in the strategic approaches is a direct result of the learning environment. Students in the physics problem-based learning course are either misinterpreting or ignoring the outlined assessment criteria for the course and misplacing their emphasis on solving the problem which should be a detriment to their grade in this environment. Whether it is a detriment to their continuous assessment and FMCE grades will be investigated in Chapter 8. As Entwistle (1991) argues, it is not the assessment criteria itself that has an effect on students approaches but in fact, the students perceptions of the learning environment. These students’ perceptions of the learning environment are examined in more detail in Chapter 6 but from the above descriptions of the approaches, it is clear that these students are either perceiving the assessment incorrectly or their overriding motives result in them disagreeing with a correct conception of the environment. Duke *et al.* does not have a comparable strategic approach, “approach C” which is a level of deep approach and *PBL strategic* is a level of deep approach but that is where the similarities end. In the Duke et al approaches to learning there does not seem to be any emphasis of intention on solving the problem instead the approaches seem to emphasise the use of resources.

Similarities can be seen between the last set of Ellis *et al.* approaches that are designated "surface" with categories being split because of the three different emphasises. The *PBL surface* approach discovered in this study shares the same functional skills and practices that are described in the set of "surface" approaches in the Ellis *et al*. study. The *PBL surface* approach does emphasise the gathering of information, especially during the recesses between classes, in the form of learning issues and also includes an emphasis on routine practices such as asking questions in the sessions, as indicated in the description above. This study did not find a discernibly suitable variation to split this category into three separate categories of description and instead found this category to be inclusive of both emphasises of gathering information and participating in a routine manner. The Ellis *et al.* paper indicates that students adopting one of these surface approaches do not have the intention of fully understanding the problem. The *PBL surface* approach, however, has a mixed intention of understanding but also of solving the problem. This may be due to students adopting this approach in the process of transitioning from *PBL surface* to either *PBL deep* or *PBL strategic*. This mixed intention is probably also a result of students trying to adopt a deeper approach without the requisite conception of understanding to achieve it and this is discussed in more detail in the next section. Duke *et al.* also found a surface approach in their problem-based learning environment with the intention of reproducing information which is part of the *PBL surface* students approach.

One major difference between the approaches discovered in this project and the ones discovered in Ellis *et al.* is the emphasis that the approaches in this research projects have on conception of understanding. This is completely understandable given the difference in subject matter and emphasis in learning outcomes. The physics problem-based learning environment emphasises understanding as a learning outcome whereas the pharmaceutical problem-based learning environment would instead emphasise the development of professional methodologies for application in the future careers of students. Overall, the superficial alignment between the approaches to learning in the two courses gives a certain amount of validation to the approaches found in this study. The differences also highlight the effects the different learning environments and course designs have had on the students approaches to their learning

5.2.6.3 The relationship between conception of understanding and previous research on meta-learning and comparison to other conceptions of understanding research.

Biggs (1985) argues that meta-learning is a state in which a student is being 'aware of and taking control of one's own learning' and so can be described as having an awareness and understanding of learning itself. In section 3.1, I discussed conceptions of learning and their apparent relationship with conceptions of understanding. I think what this study has demonstrated is that encompassed within this state of awareness and understanding of learning must be an awareness and conception of what it means to understand a phenomenon or concept. Biggs & Moore (1993) have argued that there is a link between approaches to learning and meta-cognition, believing them to be the same concept, with meta-cognition being considered to be how aware students are of their cognitive processes and how compatible these are with the learning situation. There is a tangible link between meta-cognition and approaches to learning in that the more aware of how your cognitive processes match the learning situation, the greater ability you have to adopt a suitable approach to your learning for the environment.

I believe that the students with the most developed conception of understanding are the students with the most meta-cognition, most sophisticated conception of understanding and that a student's meta-cognitive development cannot fully occur without the development of their conception of understanding. Cloete & Shocert (1986) argue that the difference between successful and unsuccessful students is awareness of approaches to learning. This argument will be revisited. However from the results of this section of the thesis, I would argue that in this learning environment the most important factor in relation to how a student approaches their learning is how meta-cognitively aware they are, in other words how developed their conception of understanding is.

Yager (2000) believes that the characteristics of a course that are designed with the constructivist learning theory in mind are very similar to those designed to encourage meta-cognitive development and Case & Gunstone (2002) argue that a shift in approach to learning is also an indication of meta-cognitive development. Lamentably, my study was not designed to examine a shift in approach to learning. However, the presence of the *PBL surface* approach to the problem-based learning environment in that study and its confused intention of both understanding and solving the problem could be an indication of a transition in approach in progress and so, in turn, an indication that a constructivist designed learning environment will result in meta-cognitive development.

The *PBL surface* approach is contradictory in nature in that it contains elements from all of the traditional strategic, surface and deep approaches. They use surface methods and describe methods of participation that can only be aligned with a surface approach and yet describe intentions of understanding from a deep approach but also the intention to solve the problem from the *PBL strategic*. I would argue that this composite of different elements is the process of students developing meta-cognitively. I would also argue that these students may have entered the course with a traditional surface approach due to their background from the Leaving Certificate and are then confronted with an active learning environment which encourages a deeper approach to their learning and so for some a transition begins to occur. I think that the *PBL strategic approach* is evidence of this transition and shows students evolving to the point where their intentions may have developed to a need to understand but they have not meta-cognitively developed to the point that their conception of understanding will allow for this intended deep approach.

This indicates that these students are trying to take control of their learning but lacking the tools to yet to evolve to a deep approach. The *PBL surface* approach demonstrates that students have evolved their intentions but have not evolved their conception of understanding and so, in turn, have not developed their study methods and participation methods to match these intentions. The seeds of meta-cognitive development have been planted in the students but only in so far as the intention element of taking control of their learning is developing. As the previous section indicated they do not have the developed conception of understanding that the *PBL deep* students do. As a result, a constructively aligned problem-based learning environment should include programs that address meta-cognition and aim to develop students' awareness of how they learn and their conception of what it means to understand a concept in order to produce a movement in students towards deep approaches.

In regards to the conceptions of understanding discovered in this study and previous research on conceptions of understanding, I make references back to section 3.1. As indicated by Saljo (1979) and Marton *et al.* (1993), there are six conceptions of learning and they split them up into two sections of laying hold of knowledge and developing an understanding of something. The conceptions of understanding which I agree are not the same as conceptions of learning but are relatable to the *PBL surface* and *PBL strategic* approaches, would appear to fall into the laying hold of knowledge category. Learning as an increase in knowledge and learning as memorising seems to encompass the *PBL surface* approaches conceptions of understanding being the memorisation of a concept. While learning as the acquisition of facts, procedures, etc. which can be retained and/or utilised in practice, would seem to have an equivalency to the *PBL strategic* approach to learning conception of understanding being based around the usage of knowledge or concepts. Whereas the *PBL deep* approach conception of understanding means understanding not just the concept itself but the different parts of the concept and how they relate together. This conception of understanding of relating concepts to others and the world as a whole would seem to fall into Saljo's learning as an abstraction of meaning. So, there seem to be associations between the conceptions of understanding and the conceptions of learning discovered previously. The fact that the *PBL deep* conception falls into the higher order of developing an understanding also gives further evidence to the approaches to learning categories and validity of calling the *PBL deep* a deep approach.

Newton *et al.* (1998) adds further validity to the conceptions of understanding discovered in this research project and to the approaches to learning concept as well, with his two hierarchical categories easily relatable to the *PBL strategic* and *PBL deep* conceptions of understanding. Understanding as a capability in application is clearly the *PBL strategic* conception of understanding as usage and understanding in establishing a mental structure is clearly the equivalency of the *PBL deep* conception of not just the understanding of a concept but its relationship to the world and the relationship of the facets of the concept to each other. One study that seems contradictory to the results of this study is the Waterhouse & Prosser (2000) research that has similar conceptions of understanding. However, that study ranks understanding when described as explaining conceptions to others, higher than understanding as application of knowledge. I think this is similar to the argument made in the description of *PBL surface* (section 5.2.3.3) approach that although a conception of understanding that is the ability to explain your understanding is a very positive conception, it depends in truth on the sophistication of the explanations. Further evidence of this lack of sophistication in the *PBL surface* approaches explanations will be posited in section 7.3.

5.2.7 Chapter summary

This chapter described the process of investigation to describe the approaches to learning, in a problem-based learning environment, of a set of problem-based learning students after one semester of teaching. An outcome space that allows for a better description of students approaches to learning in a problem-based learning environment was constructed and then the students were qualitatively placed into respective categories. The categories illustrate for the first time, a strong link between students' conceptions of understanding and their approach to their learning. Three categories of approach were discovered in total, with each linked to prior research but also exhibiting individualisms that differentiate them from traditional approaches, especially in regard to the connection to conceptions of understanding. The reasoning behind students' approaches is illustrated in the next section and correlations between approaches and perceptions of the learning environment are made.

CHAPTER 6

VARIATIONS IN PERCEPTIONS OF LEARNING ENVIRONMENT

6.1 Introduction to perceptions

As discussed in the previous section, although one of the main aims of the interview was to investigate students' approaches to learning in the context of a problem-based learning environment, a second aim was to use the interview data to examine the variations in the students' perceptions of the problem-based learning environment, in order to investigate what elements of the learning environment influence the students' behaviour and approach. This was possible due to the carefully constructed questions and line of questioning within the second part of the interviews. To clarify, a perception of environment used in this context refers to and encompasses the students' perceptions of the tutors, assessments and time spent by the students in taking part in problem-based learning. The process of analysis was the same as that described in detail in section 5.2.2.

6.2 Qualitative evaluation of perceptions

6.2.1 Categories of description

A set of categories emerged from analysis of the data, which described the variations in perceptions of the problem-based learning environment among these first year students. Compared to the approaches to learning categories which were fairly straightforward to encapsulate in a few words, the variations of perceptions were much more difficult to condense into a sentence and I went through various iterations of names. As a result of this, the names of the categories are basically how the students would describe the environment, so the problem-based learning environment is a/an:

- Inappropriate environment
- Participative environment
- Problem solving environment
- Constructively aligned environment

Each category is described below in some detail based on the empirical data within the transcripts, with excerpts from the interview transcripts which support the categories. As before, during the analysis of the data from the interviews, I endeavoured to co-constitute the meaning as well as the logical and empirical structure of the categories. I searched for themes of expanding awareness that were present in the data which served to distinguish the aspects of critical variation and highlight the structural relationship of the categories. The four distinct categories which describe the variations in the students' perception of the learning environment are related in an inclusive hierarchy, increasing in completeness. The descriptions of the categories are presented to illustrate the empirical evidence for the hierarchy. In Table 6.1 below, I outline the logical evidence for the inclusive hierarchy by stating the themes of expanding awareness and the corresponding aspects in each category which link and distinguish one category from the other.

Table 6.1 Themes of expanding awareness for perceptions of learning environment categories

Themes of expanding awareness	***Inappropriate environment***	***Participative environment***	***Problem solving environment***	***Constructively aligned environment***
Perception of purpose of environment	Not clear	To participate and get highest mark possible	To solve the problem	To gain understanding and meet assessment requirements
Role of the tutor	No role	To provide feedback	Motivational	Facilitate group work
Role of assessment	To assess if you solved the problem and group dynamics	To assess if participated in the group	To assess if solved problem and group dynamics	To assess your understanding, if had opinion, participation and research
Comfort in group	Uncomfortable, prefer to work by self or in groups of two	Often intimidated and influenced by who was in group	Comfortableness dependent on other group members and whether they pulled their weight	Liked working with other group members

It is worth noting that the "inappropriate" and "problem solving" categories have the same perception of the role of assessment. This is discussed in the descriptions of the categories and in section 6.5. It is also indicative of the relationship between perceptions and approaches for the "inappropriate" and "problem solving" categories.

6.2.2 Inappropriate environment

Within this category, students' focus of their perception is on the group learning aspects of the learning environment and how they view learning physics through group work as inappropriate. Their motivations, perceptions of assessment and descriptions of what it means to be good at problem-based learning are all influenced by their negative feelings towards working in a group. As this student describes why they do not put in the effort between classes:

Student Q: *Again it stems back to me having a dislike for PBL. That is probably the reason why I try to get through it and that is it. I get through the day and pass, that is all that matters. That probably contradicts everything I have said about physics but I don't know what it is about PBL but I just don't enjoy it.*

They have a perception that the learning environment emphasises learning to work in a group and they see this as the primary influence over the assessment scheme with learning physics in the background. The students in this category think that this emphasis on group work is inappropriate.

Interviewer: *Is there any reason why someone would be better at PBL?*

Student Q: *If you follow the guidelines you have got at PBL, that is it, the physics doesn't matter.*

Or

Student L: *Because people who are very good at physics would tend not be as good at PBL because they want to solve the problem and it is hard to get used to trying to teach it to everyone else and getting a lower mark then someone who isn't as good as physics but who is better at the PBL*

This perception of inappropriateness may be explained by the perception that learning in groups is not constructive and that students adopting this approach would prefer to work by themselves:

Student L: *It's probably better to try and teach people to work as a team with like four people, but even though, I would prefer to work in a small team.*

Interviewer: *Smaller as in 3 or 2, or 1?*

Student L: *One would be good*

This displays how uncomfortable students with this perception are in a learning environment that involves working with other people. Further evidence of this level of discomfort comes in the perception that their fellow group members are a major influence on how they behave in a group:

Interviewer: *Why didn't you gel in that group?*

Student B: *I just don't like them, pretty much. It is the individuals, it is not like I would hate them but I just wouldn't get on that well with them, I wouldn't get on with any of them.*

Their perceptions of assessment within the problem-based learning environment as mentioned is that it is focused towards how you function within the group and that to be good at problem-based learning you should like and be good at working in a group and they resent what they perceive as the focus being taken away from the physics. Another aspect of their perception of the learning environment is that they also perceive getting the solution to the problem-based learning problem as a key element of what they are being assessed on.

Interviewer: *Ok so your ability to solve a problem using a method?*

Student Q: *Yes*

Interviewer: *So that is what is being assessed?*

Student Q: *As well your understanding of the physics behind it itself.*

Importantly students with this perception also described that problem-based learning involved too much work external to the classes.

Student I: *The short time we have between the Tuesday and Thursday classes, it would be easier maybe if we had two days between, it always seemed like a very short time to get stuff done because we had a lot of work to do and sometimes it could be hard*

Finally, in regard to their perceptions of the tutors and feedback, students who perceive the environment as "dislike" often ignored feedback and only really paid any heed to it if they perceived it as accurate. They also felt the assessment and feedback was inaccurate due to the tutors missing important contributions by themselves when tutors where with other groups.

Interviewer: *What effect did feedback have, if any on you?*

Student B: *I got annoyed by most of it. Eh, I always felt that the supervisor or whatever they're called didn't always get it- didn't always understand what was happening. So sometimes you'd see what they say but that's bollocks, what are you's doing? You know? And then..I pretty much felt that about every week actually. Every week I felt that. And then I never really cared what the percent is as long as it was a pass.*

They also viewed the tutors as having no influence on the process or their learning and had no effect on their attempts to gain a solution.

Interviewer: *What affect, if any, would the tutors have on you?*

Student L: *As regards doing the problem?*

Interviewer: *Yes or how you'd behave?*

Student L: *It would be pretty much to a lesser extent than my group members anyway, I don't know if they had any bearing at all*

Overall, students who perceive the learning environment as "inappropriate" are negatively motivated by their perception of group aspect of problem-based learning taking precedence over the physics. They feel that they are aware of what it would take to do well in problem-based learning but are unwilling to do so due to their view that learning physics through problem-based learning is inappropriate. They, however, do like physics and perceive the other assessment aim other than group work as solving the problem and so will be motivated to work with the group as long as it is towards getting a solution.

6.2.3 Participative environment

Students whose perception of the learning environment is "participative" are influenced and motivated by a number of aspects of the learning environment. They are motivated by a need to get the highest mark possible but also need to be seen to be able to participate in the learning environment as evidenced by the following description of what was expected by the tutors:

Interviewer: *So a tutor would come over and you would be more active, as you put it, because you thought they expected that?*

Student H: *Yes and I didn't want them to think that I didn't know what was going on, I wanted them to see that I was doing something, that I knew something.*

This further demonstrates student perceptions of what they are being assessed on in the problem-based learning environment, with it seeming that they believe it is enough to turn up and participate in order to reach the expectations of the tutors. In turn, their idea of what they are being assessed on in the learning environment are these simple acts of participation.

Interviewer: *If you were assessing the other members of the group, what would you be assessing them on?*

Student S: *Their contribution*

Interviewer: *Ok but deep down*

Student S: *And the questions they ask and stuff.*

However this perception of participation is not the sole awareness of what is expected by the tutors. As the following extract indicates, this perception of tutor's expectations is inclusive of understanding and problem solving:

Interviewer: *I asked what you thought the biology and chemistry lecturers expected from you, what do you think the physics tutors expected from you?*

Student G: *To have an understanding of what you were being asked about, what the topic was that you were doing, to ask questions and to try and be able to put all of your effort into solving it and understanding it more so than solving it actually and to ask a lot of questions, they really expected that.*

So these students' are aware that there is more to a problem-based learning than participating and yet participation is the focus of their perception of the learning environment. These perceptions are conflicted in nature in that tutors expect understanding and solutions but assess on how much you participate. Unlike the "inappropriate" perception of the learning environment, these students have positive feelings towards problem-based learning but their level of comfortableness in the environment is also affected by their group members. So their level of participation is affected not by whether they like their fellow group members but instead by how intimidated they feel in the group.

Interviewer: *So it wouldn't matter what group you would be in, it would be the same?*

Student A: *No not necessarily because when I was in the first group, even if I was in that for the last group I think I wouldn't have talked as much just because I think they all were really good at physics and I didn't think that I was and I would have still been hesitant just to ask questions.*

Another major element of this perception that is tied to the above intimidation is how much prior knowledge and the knowledge garnered from learning issues carried out in-between classes has on their level of participation.

Student F: *When you are put in your induction you are told that you don't need physics and that was a relief when I heard that but then when I went into the first PBL it was like, yes I did need physics, yes I did.*

Like the "inappropriate" perception of the learning environment students whose perception of the learning environment is "participative" also believe that to be good in a problem-based learning environment you must both like and be good at working in a group.

Interviewer: *So physics versus group work, which is more important in PBL, the ability to work in a group or to have prior physics knowledge?*

Student H: *To survive you have to have the ability to work in a group. You are not going to survive PBL if you cannot work in a group.*

As can be seen they have the same perception that to do well in the problem-based learning environment, physics is not as important as group work. A slight difference between the "dislike" and "participation" perceptions of the learning environment in regard to what it means to do better at problem-based learning is that the "participation" students have a more insightful description of what it means to be better at group work and these advocate that listening to others is an important aspect of working in a group as well as asking questions as the following excerpt indicates:

Student G: *One that was good at explaining, one that explained everything and not just what they didn't know when they were asked questions and had step procedures as to how it was being solved, not just jumping from one thing to another and leaving out the fuzzy bit in the middle because you didn't really understand that. Somebody who was like, no we are going back to do that and we are not skipping because we don't understand it. Someone who liked asked those questions to get that solved and done the research in-between, would be the ideal PBL student.*

Again as indicated in the above extract, when describing tutor expectations, participative students have an enlightened take on what it means to be a good student in problem-based learning but again this does not match the students perceptions of the assessment criteria and tutor expectations. Finally, in regard to tutors, the participative perception does perceive tutor feedback as having an effect but overall the tutors did not have much of an effect on them:

Student A: *Like if I was asked to ask questions in the feedback would I ask more questions?*

Interviewer: *Yeah*

Student A: *Oh em yeah if tutor said and I remembered do you know that way if you remembered what was said then you'd be like awh yeah just try and try and beef up little bits and say awh yeah*

Interviewer: *OK em what affect if any would the tutor have on how you performed individually?*

Student A: *Not a lot*

Interviewer: *No*

Student A: *I kinda, you did what you could do, do you know that way like from the background in physics you had and the time you had between the classes*

Overall, students who have the ‘participative’ perception of the learning environment perceive a key aspect of the design as being expectancy of understanding but focus their perceptions on being seen to be participating. This motivation is influenced by prior knowledge and group members and unlike the “inappropriate” perception, students with the participative perception dislike the environment and really just want to get what they conceive as a good mark.

6.2.4 Problem solving environment

The “problem solving” perception of the learning environment is influenced by students perception that their priority is to solve the problem and this is also their focal motivation, to the point that once they have found the solution, their main source of motivation is gone and they stop participating in the learning environment:

Interviewer: *Ok. The ideal situation would be to get a solution though?*

Student O: *Yeah. Yeah. So actually a lot of the time we’d get a mathematical solution but a kind of- if it, especially the ones where you- its more just explaining the physics of it.*

Interviewer: *Um-hum*

Student O: *It em, I dunno. I kinda lose interest then*

Like the “participative” perception, prior knowledge influences these students but in a motivational manner in the same way solving does. Both the quality of their prior knowledge and how well the solving is going, motivates the students to participate:

Student J: *If I had motivation, if I understood a bit of it, I'd be like oh cool this is working out for me, I'd be more, but if I kept on getting, kept on getting stuck and was asking questions of everyone else in the group and they didn't know anything I'd be like ah fuck this I don't give a shit anymore*

Another element of students motivation is also the tutors who they perceive as a motivating presence. Students often do not put effort into learning issues or participating unless the tutors are present which is contrary to the previous perceptions of the tutors having no real effect:

Student O: *(sighs) Um, yes I'd say I would. Like sometimes if they're not there and we're not really meant to be doing anything sometimes I'll even think 'we have so much to do'. We'll save any good talking until they come around and they can see it (smiles) and I'll just switch off on those times and we'll talk about other things*

In relation to the tutors, again like the other approaches discussed to this point, those students with the "problem solving" perception do not see the tutors as an essential part of the learning that occurs in problem-based learning but do perceive them to be a motivating factor. They also pay attention to feedback provided by tutors and reflect on it to see if the tutor has a point.

Interviewer: *Would you tailor what you're doing so would you try and show that you had listened to the feedback in when a tutor came over?*

Student R: *Em yeah I suppose you would, like, if you hadn't done if your feedback said you didn't do your learning issues*

Interviewer: *Um-hmm*

Student R: *Probably enough, you would go away and say I have to, I'm going to get these done now properly so that when they ask me I'll know I'll be able to tell her or him. Like sometimes I was taking over writing too much like and I wouldn't have realised kinda, like, I did it without being aware I was doing it. Like I was just you know, continued writing once I started but eh if it said, you know like, give other people a chance, I definitely would coz I didn't wasn't didn't realise I was doing it as much as I was, do you know so yeah definitely*

Along with these positive perceptions of the tutors though is frustration with them as well when they were found to be unhelpful in getting to a solution fast which would be expected in a perception that emphasises problem solving as the motivation:

Student P: *Em, sometimes when you ask a question and you don't get a direct answer it can be a little frustrating. I know they're trying to get you to think but*

Interviewer: *Um-hum*

Student P: *It's a little annoying (laughs)*

In respect to comfortableness in working in a group, there are no perceived influences from fellow students and no animosity towards working in a group other than some indications that they perceive that, sometimes, other group members are not putting in the same effort as themselves. Besides this, "problem solving" students have what the course designers would consider good perceptions of what group learning involves and what the tutors expect of students in a problem-based learning environment. These descriptions by students of tutors expectations are focused on group aspects of the learning environment, such as peer tutoring or working well in a group but also, similar to the "participative" students, they focus on asking questions and being involved.

Interviewer: *What do you think your physics tutors expected from you?*

Student M: *They expected us to be very concentrated on the problem, to go through everything with each other and peer tutor and learn a lot more about the problems.*

The attitude of 'problem solving' students to assessment is the same as the 'inappropriate' perception with their perceptions of assessment being a combination of contribution to solving the problem and how much you helped others.

Interviewer: *What would you be assessing them on?*

Student M: *I'd be assessing them on how they helped the others in the group or if they tried to solve the problem, their contribution to the solution and did they help other people to solve the problem?*

These perceptions of what the tutors expected and these students perception of assessment are in direct conflict with what motivates students of this category to work in the groups. Their almost singular motivation of solving the problem cannot be aligned with the perceived tutor and assessment expectations. Again, like the previous conceptions they view the ability to work in a group to be more important than physics knowledge:

Interviewer: *Your knowledge of physics versus ability to work in a group, which is more important to do well in PBL?*

Student T: *The ability to work in a group because just because you are good at physics doesn't mean everyone else is, so if you can't help them along you are just going to be held back yourself.*

Like the previous perception of "participative", these students are aware of some of the most encouraged group work skills and methods of participation. But overall, this perception of the learning environment is one that misaligns the motivations of students with their perception of the expectations of the tutors and, in turn, their perception of how they are assessed in the learning environment. This is similar to the "participative" perception which misaligns the students motivation of wanting to participate plus get high marks with their understanding of tutor expectations and perception of the assessment criteria or to the "inappropriate" perception who cannot see past their dislike for the learning environment to attempt to align their perceptions of assessment to tutor expectations or their motivations of trying to solve the problem.

6.2.5 Constructively aligned environment

The final perception of students of the problem-based learning environment is "constructively aligned" which is to say that students with this perception of the learning environment are aware of the multiple facets of assessment and tutors expectations that are involved in a problem-based learning environment. In many ways, their perception of the learning environment, of tutors expectations and of assessment matches those of the course designers and hence they are 'constructively aligned', though they would not use this term.

So the “constructively aligned” students are motivated by the assessment goals of the course. They are positive towards problem-based learning and physics. They enjoy learning in the problem-based learning environment and other motivational factors such as topic of the problem, ability to solve or other group members that were indicated in the previous descriptions of perceptions, do not affect these students.

Student E: *Yes definitely, I know that at the beginning I was really enthusiastic about it and by the end I was a little bit frustrated, but that was more a consequence of the fact that I realised that I couldn't step back and let the group... I was frustrated with the fact that I always seemed to feel that I had to take control and find every solution and so on. But I thought it was brilliant right from the start.*

Their singular motivation is to prosper and achieve good assessment marks within the confines of the assessment as outlined by the tutors. They are aware that the tutors expect them to understand and that this awareness of understanding is not limited to the problems but that they should be aware that there are always other aspects of the concepts discussed in the problem to understand.

Interviewer: *I asked you what you thought the biology and chemistry lecturers expected from you, what did the physics lecturers expect from you?*

Student E: *It actually felt like they expected no prior knowledge and I am not just saying that, it really felt like they expected no prior knowledge, that the expected the solution to come organically, as far as I am aware, from just having the target in mind. They expected us to see the need to research something and to go and do that and come back with the answers or knowing enough about the subject to be able to answer the question given. I assume they expected us to realise that there was more to be understood, that you'd need to look at this topic again, there was much more detail than was going to necessarily be covered in class.*

As can be seen from the description above, these students perceive understanding as one of the expectations of the tutors but that those expectations also include knowing how to work in a group, to research and to take part. This is a more complete view of tutor expectations of understanding and is one of the aspects that distinguish this perception from the previous. Another aspect is that these students also believe that the tutors expect them to be aware of what they are being assessed on. This is an expectation that is unique to this perception of the learning environment but is in keeping with the tone of awareness of assessment that runs throughout this perception.

Interviewer: *I suppose it is almost in terms of assessment that you would be aware of what they were marking you on.*

Student N: *Oh yeah, I think they expected us to know, that didn't stop me, but I was aware, I knew from what they said how we would be marked but it didn't really influence me that much.*

Another individualistic expectation to this perception is that these students also believe that the tutors expect them to have their own opinions.

Interviewer: *I asked you why you thought your chemistry and biology lecturers expected from you in a lecture, what do the physics tutors expect from you in PBL?*

Student N: *Well I get the feeling that rather than you just being told certain facts and things that your own opinion is asked a lot more, rather than just being told how something works, you are actually asked questions and pointed in the right direction and you are actually made think about the question and most people generally have the answers.*

Again this expectation would be aligned with the designer's expectations of the course, as a collective understanding from various different opinions on concepts is the desired outcome in a problem-based learning environment, as described in Chapter 2. However, the 'constructively aligned' perception does indicate some distinctively different perceptions, from those of the other categories, on what it means to be better in a problem-based learning environment, with much of the emphasis on group skills such as the ability to explain yourself and your understanding. Students with this perception also understand that a willingness to explain slowly, if needed, and to listen to the explanations of others would result in them being a better student. They also indicate that there is a need to not be solution driven and, instead, to set yourself learning goals for the problems.

Student E: *Well no you can't because it varies I think depending on the rest of the participants. A group of ideal students might be easier to describe or the ideal group of ideal students, but that is stretching a bit. Primarily it is a group that is not just solution driven but has a learning goal in mind as well or recognises that the problem and solution are there with a greater scheme of things in mind to help you approach a greater scheme of things. That is* *one of the things that would make a perfect group. So how well they work together, they'd have to not just participate but help the group to come to the solution and help the group to recognise all of the issues. So it the perfect participant in that group would be someone who plays their own part and contributes towards the solution but also encourages the others to bring their solution to the table and things like that.*

Finally, these students have positive views of the effect of the tutor although not in a motivational aspect as in the "problem solving" perception but they see tutors as encouraging explanations and helping if they are stuck in the problem. Such students also pay attention to the feedback given to them throughout the year. They also indicated that they felt that the written feedback was always justified and that they would consistently reflect on it.

Interviewer: *That leads me on to tutors, what affect if any would the tutor have on how you performed individually?*

Student E: *Well it was clear that it was the tutor's responsibility to facilitate group work and that they were there to challenge us and to draw out, well to draw us away from reciting stuff that we got from the books and actually explaining what we had learned. So they encouraged or I felt encouraged by the tutor to explain things, not to the way that I understood but in a way that other people... No that doesn't make any sense, what I mean is that they encouraged us to explain things in our own words to the others and in a way that we understood ourselves so that if I was explaining something that I understood it first and then explained it. Because that was the acid test always, you could hear when somebody else understood what they were saying because they were explaining it in their own words. It sounds like I am just rhyming off what you want to hear but that is just coincidence.*

Overall, the "constructively aligned" perception of the learning environment is a perception that is based around the students matching their perception of the expectations and assessment procedures with their motivations. They are overtly very positive towards the learning environment and have set very similar learning goals to those set by the course designers and their motivation is to meet these goals. So their awareness of assessment criteria, purpose of problem-based learning and their perception of the expectations of the tutors all inform their motivations for the course.

6.2.6 Summary

From analysis of the data from the interview transcripts, four distinct categories emerged that described the variations in these students' perceptions of their learning environment. Specifically students' perception of what was expected from them during the course of their study in introductory physics and how their perception of different elements of the problem-based learning course affected their perception of what was expected. The presence of the hierarchical structure demonstrates different levels of awareness of the different elements that contribute to a student's perception of the problem-based learning environment. For example, the *participative* or *inappropriate* perceptions of the problem-based learning environment include a perception of the tutors as having no effect on them within the problem-based learning sessions. They, in essence, have no perception of the purpose of the presence of the tutor or how tutors contribute to the problem-based learning environment. However, as we move higher in the hierarchy, the perception of the tutor changes to including elements of what they do and the effect they have. The four categories will be discussed in relation to previous perceptions of learning environment research and the approaches to learning research presented in the following sections.

6.3 Discussion of variations of perception

As was discussed previously in Chapter 2, there is a construed relationship between a student's approach to learning and their perception of the learning environment (Entwistle 1987). Ramsden (1987) argues that an approach is both a function of the student and the context. This study took the concepts of perception and approach separately and so constituted them individually from separate phenomenographic analyses but with the implicit intent of relating them and examining the relationship at a later stage. This examination of the relationship is presented in section 6.5 after the students are assigned to the previously described categories for approaches to learning. The aim of this element of the discussion is to examine how the perceptions found in this research project relate to other perceptions that have been found previously.

Fundamentally, the most important finding from the perceptions of learning environment research in this study is the role meta-cognition plays in students perceptions of the learning environment. The constructively aligned category of perception, as will be seen in section 6.4, has a direct link to the *PBL deep* approach which is the most meta-cognitively developed category and has the most sophisticated conception of understanding approaches to learning in this environment. So the more meta-cognitively developed the students, the greater their perception of the learning environment and the more aware they are of how their perception of the learning environment affects how they approach their learning in that environment. This is evidenced by the fact that the constructively aligned students appear to relate their perception of assessment, their expectations of tutors and their approach to the learning environment in the same way as the course designers would have intended. This relationship of deep approach with a deep perception has been found before (Meyer *et al.* 1990).

In a study by Trigwell & Prosser (1991), they found that the perception by students of good teaching, clear assessment goals and learning independence resulted in a deep approach. The *constructive alignment* perceptions of the multiple aspects of the assessment system used in the problem-based learning environment is an obvious illustration of how students perceive the assessment goals of the environment to be clear. As was indicated in the description of the *awareness* perception, these students align the assessment goals with their perceptions of tutor expectations and their own motivations in a strikingly similar way to those which the course designers would encourage. Similarly, the learning independence aspect of the Trigwell and Prossser *"deep"* perception can be found in the *awareness* perception in the students' awareness that there is always more to understanding the area of physics a problem is investigating. The awareness that they are expected to look beyond the problem and investigate further is not present in the other perceptions. This is interesting in that this is a learning environment that is supposed to be designed to promote learning independence and yet there are three categories of description of perceptions that exclude this awareness from their descriptions. The majority of students do not perceive learning to be independent beyond the fact that it is inherent in that they have to complete the learning issues. In fact the *inappropriate* category seems to abhor this element of the learning environment indicating it as one the reasons for their dislike of the learning environment.

Student: *Yes but with the PBL, I personally, would learn less, as in I wouldn't go off and study everything about the concepts of a question because I have to come into a class and I have to speak about these learning issues and I will get marks for that and that is grand, but if I had to go off and study for a test or a lecture or something like that, I would sit there and go, all right this is what I have learned, I have to learn a bit extra of that, grand. Personally, it is something I probably should study more in PBL but there is just something, I don't know why, but I don't study as much, I know it is weird but I just don't study as much for PBL than if I was studying for chemistry lectures.*

It is apparent from these findings that in order for a learning environment to promote a deep approach, not only must it be perceived as encouraging learning independence but students must also be able to perceive that it is encouraging learning independence. Finally, in regard to students perceiving good teaching, Ramsden (1992) describes good teaching as teaching that involves giving helpful feedback, making an effort to understand the difficulties students may be having, being good at explanations, making subjects interesting, getting the best out of students, motivating students and showing an interest in what the students have to say. It is clear from the *constructive alignment* students' perceptions of the tutors that the problem-based learning tutors would fall in this blanket term of 'good teaching'. Also, it is apparent in the *problem solving* perception of the learning environment that they view this good teaching aspect of the problem-based learning environment. In fact, the presence of good teaching in the *problem solving* category is consistent with the phenomenographic methodology that one category encompasses those categories which are lower hierarchically (Marton & Booth 1997). Both categories emphasise that the tutors are helpful in many aspects in the learning environment and this is apparent in their positive and reflective view of the feedback given to them by the tutors.

The *inappropriate* and *problem solving* perceptions of the learning environment are discussed in more detail in section 6.5 below, as it becomes clear after relating students approach to perception that they are fundamentally linked to the *PBL strategic* approach.

As discussed previously, all the approaches found in this study are particularly individual to this learning environment and so it is difficult to discuss them in relation to previous research without the relationship between approach and perception being apparent. However, in relation to the *inappropriate* perception of the learning environment Nijhuis *et al.* (2005) found that students' negative perceptions of different aspects of the problem-based learning environment have acted as a block to the deep learning strategies which the environment is designed for which might explain why these students adopt a more strategic approach. In the same vein, Entwistle *et al.* 1991 presented evidence of students having confused perceptions of the learning environment. The apparent confusion between the link between their perception of the learning environment and their approach to their learning which corresponds to the *participative* perception of the learning environment and the *problem-solving* perception both of which are confused in relation to their perceptions of assessment and motivation. The relationship between this confusion and approaches to learning is discussed in section 6.5.

The presence of these correlations and relationally equivalent perceptions between this research and past research on perceptions of learning environment especially in relation to the *constructively aligned* perception in the problem-based learning environment validates the phenomenographic approach used and these problem-based learning perceptions of the learning environment. It could be postulated that because the students would have had the same limited prior experiences of a problem-based learning environment and since they would all have similar experiences of the learning environment from the start, then perhaps a uniform perception of the learning environment might have developed among the students. From the results above, this is obviously not the case, with several different perceptions of the learning environment having been discovered. It could be argued that the themes of expanding awareness would be the major factors that influence a student's perception of this learning environment. If these are indeed the major factors that influence a student's perception of the learning environment then how does it come to pass that they perceive these factors in such a differing manner. I believe part of this answer is again in each individual student's meta-cognitive ability. That is, their ability to reconcile their own knowledge of their cognitive processes with their perception of the learning environment as discussed above. So again, as in the approaches to learning conclusions (section 5.2.4) meta-cognitive awareness is a major influence on the results of this study.

Duke *et al.* (1998) using a phenomenographic technique found four conceptions of the problem-based learning environment. Although these are conceptions and not perceptions there is a certain amount of correlation between my studies perceptions of the learning environment and Duke et al conceptions of the learning environment. The first category of "process only" with a conception of a process that is activity based could be associated with the "participative" perception and those students seeing the goal of the learning environment is to be seen to be participating in the process. "Process/purpose (problem-solving)" could also be correlated with "problem solving" where the students conception is that learning occurs through the process and solving the problems and the perception is that their motivation and perception of the point of problem-based learning would be to solve the problem. Finally the "Process/purpose (understanding/contextualising/personal goals)" conception draws obvious parallels with the "constructively aligned" perception as both display an almost expert awareness of how the problem-based learning environment should be conceived and perceived. These apparent correlations exhibit that, as would probably be expected, there is a relationship between students' conceptions and perceptions of a leaning environment.

6.4 Putting students into categories

The same method that was used to place the students in categories for their approaches to learning was repeated at this stage in the research which again moves away from the phenomenographic approach. As previously described, during the analysis of the transcripts the categories were constituted from all of the data from the interviews and no one student can necessarily be described by a single category. However, once analysis was complete and the stable categories were constituted, it was possible, for illustrative purposes, to place individual transcripts within the category with which I most identified them in regard to their perception of the problem-based learning environment. Again, placement of students into categories was based on the themes of expanding awareness, by judging which transcripts had the greatest association with the themes of expanding awareness for each category. The table below presents the various students and their associated perceptions of the problem-based learning environment.

Table 6.2 Students placed in perception of learning environment categories

Perception of the learning environment	Students associated with perception
Constructively aligned	Student E Student N
Problem solving	Student O Student M Student D Student J Student P
Participative	Student A Student F Student G Student H Student K Student R Student S Student T
Inappropriate	Student B Student C Student I Student L Student Q

The table above illustrates the perceptions of the learning environment category for each student and the next section discusses these perceptions of the learning environment in relation to the approaches to learning categories previously presented and previous research which relates to the findings above.

6.5 Discussion of perceptions plus approach

Table 6.3 illustrates the perceptions of the learning environment and the respective approaches to their learning that students with these perceptions adopted to the problem-based learning environment. The table was formulated by matching student approaches as evaluated in section 5.2.5 with the perceptions for the same students which were presented in section 6.4.

Table 6.3 Relationship between approach and perception

Perception of learning environment	Corresponding approach to learning
Constructively Aligned	*PBL deep*
Problem solving	*PBL strategic*
Participative	*PBL surface*
Inappropriate	*PBL strategic*

As is apparent from the above table, each perception has a self contained approach associated with it. For example there were no cases where an *inappropriate* perception student had a corresponding *PBL deep* approach and all the students with the *constructively aligned* perception had a corresponding *PBL deep* approach and so on for all perceptions. It is also worth noting that the *PBL strategic* approach is not reciprocal with just one perception. Therefore having a *problem solving* perception of the learning environment means you would have a *PBL strategic* approach but as can be seen from the table 6.3 having a *PBL strategic* could be prescriptive of one of two perceptions. The linked relationship between approach and perception adds further evidence of previous research findings of Ramsden (1987) and Thomas & Rohwer (1987) that perceptions and approaches are relational and an approach is a function of both the student and the context. What the above table also begins to illustrate is the motivations and reasoning's behind the *PBL deep* and *PBL surface* approaches while also illustrating that there can be different motivations and reasoning's for a student to adopt a *PBL strategic* approach.

PBL deep/constructively aligned

Examining the *PBL deep* in more detail with its associated perception of *constructively aligned* it becomes clear that students adopting this approach relate their motivation, perception of learning environment, perception of assessment and their approach in the constructively aligned manner the course designers would have hoped. They are aware of what the learning environment expects of them and then approach their learning in order to meet these expectations. Segers *et al.* (2003) argued that for students to achieve a deep approach in a learning environment such as problem-based learning then the assessment scheme in the learning environment should be constructively aligned. From the correlation between the *PBL deep* approach and *constructively aligned* perception it is apparent that it is not sufficient for the learning environment to be constructively aligned but that the students within the environment must also constructively align their perceptions of the assessment, their expectations of tutor and their own motivations in order for a constructively aligned environment to effect a student's approach. In essence, in a deliberately designed constructively aligned environment, students must be able to perceive and more importantly agree with the alignment in order for them to take a deep approach but this ability to perceive is dependent on how meta-cognitively aware the students are in order to actually perceive the constructive alignment of the environment in the first place. Put simpler and as asserted by Meyer & Muller (1990), deep students are more aware of their learning environment and so the more aware you are of the environment the more you can perceive it to be deep.

From the correlation between the *PBL deep* and *constructively aligned* categories it is also apparent that students who adopt a deep approach are very positive towards problem-based learning, physics and working in groups to solve problems and do not let other factors such as the members of the group or the topic of the problem influence how they approach the learning environment. As was indicated in section 6.2.5, these students also have a positive view of the effect tutors have on them and see them as a complementary part of the learning environment. There are two main motivations for these students: to do well on the assessment criteria and to understand the material they are learning. This fundamental understanding ties into their view on the assessments as well. Perceptions of end of semester assessments were not included in perceptions of learning environment as I did not feel it appropriate but it is included in the student profiles, Chapter 9. *PBL deep* students claim that the end of year assessment was testing their understanding. After the correlation between approach and perception, it is clear that their evolved view of understanding matches the conception of understanding that is being tested in the assessment and so they should have prospered under such assessments. This premise is answered in Chapter 8 where the now *PBL deep/constructively aligned (approach/perception)* is correlated with both assessment results and the FMCE. In summation, the *PBL deep* approach is a result of positive feelings towards the learning environment and a perception of the assessment criteria and expectations about tutor that match their own motivations and are matched to the constructive alignment of the learning environment.

PBL surface/participative

The correlation of the *PBL surface* with the *participative* perception gives the approach a much clearer definition and links it to past research. Traditional surface students have the intention of coping with the course requirements (Entwistle 1997). Again, the correlation between approach and perception gives evidence of this coping. In fact, evidence is even apparent in the name of the perception category *"participative"*. The coping mechanism in the problem-based learning environment manifests itself in students who take this approach wanting to be viewed as participating. If they do not have sufficient prior knowledge to participate in the first session then they will diligently work on their learning issues between sessions in order to participate in the next session (i.e. cope).

This link to the traditional description of surface approaches reinforces the *PBL surface* approach to a certain degree but the correlation with the *participative* perception also adds further evidence of the confusion that this approach entails. For example, students perceptions that tutors expect them to gain an understanding in the problem-based learning sessions but only really assess on participation is confused in nature especially when the approach is to participate in a surface manner. Hazel *et al.* (2002) and Prosser & Trigwell (1999) both found an incoherent relationship between perception and approach with some students perceiving a need for a deep approach but not adopting one. I believe that this is more evidence that students adopting the *PBL surface* approach are just not meta-cognitively aware enough to establish the flawed logic in their approach or the misalignment of their perceptions with their approach. This is evidence again that students may have the perceptions needed for a deep approach by the problem-based learning course but have not been equipped with the meta-cognitive awareness to evolve their cognitive processes and so are ill equipped to deal with these perceptions. Biggs (1996) found a similar result in that students could perceive that a deep approach was appropriate for the learning environment in his study but they did not know how to adopt such an approach. It is difficult to say conclusively that this is happening in the *PBL surface* approach. The students do perceive the need for understanding but have not achieved a level of awareness to understand that their current surface approach will not be sufficient to succeed in regards to the tutors conceptions of success in the learning environment. They may well be succeeding in their opinion if “passing” is success. Another possible explanation is that the students perceive the tutors correctly and it is in fact the tutors expecting different things from different students that results in the confusion between tutor expectation and perception of assessment. This may warrant a further investigation into tutor’s perceptions of assessment and their expectations of students in the problem-based learning environment.

Like the *PBL deep/constructively aligned* discussion above, I feel it important to jump ahead to students’ perceptions of end of year assessment and discuss how *PBL surface/participative* prepare for these assessments. The method of preparation for an exam which they regard as testing both understanding and problem solving is to attempt to remember and then reproduce methods of solution. Marton and Saljo (1976) describe the surface approach as students who have a ‘reproductive’ conception of learning and although the approach to solving problem-based learning problems is reproductive in nature, this approach to assessment further asserts that *PBL surface* has elements of the traditional surface approach. The fact that these students perceive end of year assessment as assessing understanding plus problem solving but they prepare by memorising methods of solution is further evidence of this approaches’ low levels of meta-cognition. Given their unsophisticated conception of understanding one would imagine that when displaying their understanding in assessment, they would not be very successful. This is examined in Chapter 7.

These students also perceive the tutors as having no effect and in the past this has also been attributed to a traditional surface approach to learning (Trigwell & Prosser 1991). External factors such as the topic of the problem, prior knowledge and the students in their groups seem to be all motivational factors which is unlike the *PBL deep* approach that related none of these factors to motivation. The biggest motivational factor is to do well in the course but it is these students' misperceptions of assessment and what is involved to do well in the problem-based learning environment that leads them astray.

PBL strategic approach

Due to the differing perceptions of the learning environment of the *PBL strategic* students the following discussion will be split up into two segments:

PBL strategic/inappropriate

I think it is important to emphasise that although these students have a very negative perception of the problem-based learning environment and so in a hierarchical arrangement would appear at the bottom of an approach/perception pyramid, it is the fact that they are strategic and so can choose to gain an understanding of a concept or problem if stuck instead of continually using surface methods that makes the approach more evolved than the *PBL surface/participative*. Biggs (1985) suggests, students capacity to select strategies which are appropriate to the particular task reflects their capacity for meta-learning and in turn how meta-cognitively evolved they are. As was suggested in the description of the *inappropriate* perception, the over powering influence of the dislike of students for the learning environment, results in students adopting an approach that emphasises solving the problem. So it's quite possible that this approach would not exist and instead the students who would have taken this approach would instead have taken a *PBL deep* approach or *PBL strategic/problem solving* approach, were it not for their conception of inappropriateness for the learning environment. However, they are in the problem-based environment and so reconcile with it by concentrating their attention on the one element of the environment that they are okay with which is solving physics problems.

It has been indicated in past research that the phenomenon of individuals having issues with working in a group has been related to the adoption of a surface approach by students (Kember 2004; Ramsden & Entwistle 1981; Entwistle & Ramsden 1983 and Trigwell & Prosser 1991). However, there is no evidence of students with the *PBL strategic/inappropriate* approach/perception being limited to a surface approach and this seems to be down to their sole motivation to get a solution to the problem. When confronted with situations where their attempts at solving using a surface approach are blocked, they will adapt to understand the physics concepts in order to solve the problem. This understanding, as stated in the description of the *PBL strategic* approach, comes in the form of obtaining a working knowledge of the concepts. So they might not understand a concept at a fundamental level but will have the ability to attempt to understand the concept enough to use it to solve the problem. Importantly these students have enough meta-cognition to be able to ascertain what is needed to solve the problem unlike the *PBL deep/constructively aligned* who would have this ability too but would always choose the path to a deeper understanding. The same is true for the *PBL strategic/problem solving* with the only difference between this category and the other category *PBL strategic/inappropriate* being those issues that influence these students to take the strategic approach. In this case, it is their perception of the inappropriateness of the learning environment and their perception of an over-emphasis on the group elements of the assessment and learning environment.

The fact that students who exhibit the *PBL strategic/inappropriate* approach/perception display perceptions that are normally attributed to students adopting a surface approach such as a heavy workload and their perception of their own negative performance (Entwistle & Tait 1990) in the learning environment and yet still approach their learning in a strategic manner is both positive and an indication that perhaps the learning environment does not have as much as an effect on approach to learning as their own motivation to solve the problem. This thread of the discussion will be picked up again in the Chapter 7.

PBL strategic/problem solving

This approach/perception has the same motivation as the *PBL strategic/inappropriate* to solve the problem but instead of this being influenced by disliking everything about the learning environment to the point of only focusing on the physics problems themselves, these students perceive the assessment scheme as focusing on solving the problem. So a *PBL strategic* approach can be the result of two different perceptions of the learning environment with both perceptions based on solving the physics problems. As was iterated in the previous section of the discussion, the fact that two very different perceptions of the learning environment can result in a student taking the same approach is evidence that perhaps the student's perception of the learning environment is not one of the greatest influences on the approach that student will take to their learning in the learning environment and instead it seems that an overriding motivation can affect approach more than perceptions of learning environment.

Students with the *PBL strategic/problem solving* approach, unlike the *PBL deep/constructively aligned* approach are influenced by external factors. In this case, it is whether they perceive they can solve the problem and if they have required prior knowledge to do so. The students adopting this approach/perception do perceive the tutor expectations and assessment criteria in much the same way as the course designers intended including understanding and group work but with an over-emphasis on solving for the purposes of the assessment. The reasoning behind this may be their educational background in much the same way as with the *PBL surface* approach, priority of both solving and understanding could be evidence of students in transition. So too could the fact that *PBL strategic/problem solving* students have the correct perceptions of assessment and tutor expectations but the wrong motivation. These students divorce these perceptions of the learning environment from their motivation of solving the problem. That is the main differential between previous strategic approaches and the strategic approach described in this study. Their motivation and intention is not getting good grades from the assessment instead it is to just solve the problem. As was previously mentioned, Biggs (1985) suggests that students' capacity to select strategies which are appropriate to the particular task reflects their capacity for meta-learning and this is evidenced in the preparation of these students for the end of year assessments. They seek understanding by reading books, doing examples and although this understanding is in the form of usage, their awareness that a plug and chug or memory approach to the exam will not be successful is a further indication of their more advanced meta-cognitive level than the *PBL surface/participative*.

As indicated in the literature review in section 2.3.12, the change from secondary school to college can be a time of great upheaval and academic uncertainty (Fisher & Hood 1987, 1988) and Hejka & Chur-Hansen (1995) argue that there are transitional problems and an adjustment period associated with moving to a group-based learning environment especially where former academic performances were obtained through individual success on a competitive basis which the Leaving Certificate would have been. This implies that some students will adjust faster than others and the approaches to learning found in this study could be merely a snapshot of students approaches to learning after completing one semester of problem-based learning. There is some evidence in the approaches themselves in regard to the *PBL surface* approach priority of solving and understanding or the *PBL strategic approach* overriding motivation to solve the problem even though they perceive that the assessment and tutors expect understanding. However, this study can give no conclusive evidence as to whether these approaches are influenced by the time at which the study took place and whether the approaches are transitional approaches. The only way of proving either way would be to complete a longitudinal study of a set of students and investigate their approaches at several points in their problem-based learning course.

6.6 Chapter Summary

Four perceptions of the problem-based learning environment in which this study is set were discovered and correlated with the previous approaches to learning discovered for this learning environment. The correlation of approach to perception indicated that students primary intention would appear to have the most effect on how a student approaches the learning environment and their primary intention is affected by their perceptions of the learning environment. Further proof was also demonstrated of the effect of students' meta-cognition awareness on the approach they take in the problem-based learning environment. It is apparent from the research presented above that students can perceive the assessment and tutor expectations that should encourage them to take a deep approach but can not be motivated to do so. It is also apparent that students can perceive an assessment criteria that requires a deep approach but lack the meta-cognition and conception of understanding to adopt a deep approach.

CHAPTER 7

ACTIONS IN THE PROBLEM-BASED LEARNING ENVIRONMENT

7.1 Introduction

The previous two sections described the approaches to learning and perceptions found from phenomenographic analysis of a group of students enrolled in the problem-based learning environment resulting in the aligned categories of *PBL deep/constructively aligned, PBL strategic/problem solving*, *PBL surface/participative* and *PBL strategic/ inappropriate.* The following section aims to illustrate how the students manifest these approaches/participations in their actions in problem-solving sessions in the problem-based learning environment. Here the findings from the analysis of the video data are presented and then discussed in relation to the findings so far in this study and relevant studies from the literature.

As discussed earlier, the intention behind the data obtained was to examine students' actions over the period of time that they were tackling the mechanics section of the problem-based physics course. The data is presented according to the different categories mentioned above. A description of the findings for each approach/perception are presented and the chapter concludes with an in depth discussion of the findings from the observation data. The findings from the FMCE are then be presented and discussed in the next chapter.

7.2 Actions data analysis process

As discussed in Chapter 4, video data was taken of six groups of four students over a two year period and involved the recording of each of the six groups for eight problems. Each problem involved two sessions of two hours each of group problem solving. From this data three groups were chosen to be analysed for their actions over three separate problems. The problems chosen were equally spaced over the entire mechanics section. One from the start, one midway through the section and one at the end of the section were chosen in order to give a complete view of the students' actions over the entire time period. By doing this in this spaced manner, it also enabled the observation of any changes in behaviour as the students progressed over the time spent in problem-based learning. Although I had data for all of the problem-solving sessions and indeed for all of the groups involved in the research, I did not deem it necessary to analyse each group over each problem in order to get an accurate portrayal of the students' actions.

The analysis process included five problem-based learning tutors as well as myself. The analysis consisted of two tutors paired together, analysing separately, looking at each of their assigned set of videos on a number of occasions while making notes on the students' actions. Once a complete set of notes had been finished the tutors then met and compared and contrasted their results until an agreement, between each group of two, of the students' actions for the different sessions was reached. When each group of two had completed this process, the groups came together and again compared and contrasted their results paying specific attention to an agreed language for each comparable action. With this agreed language determined, the maps of the students' actions were given to me to produce the results written in the language agreed upon and presented below. Initially, tables of actions for each individual student were produced from the analysis of the three pairs of tutors and can be found in Appendix H. The tables of actions for each student were then examined in groups with the groups consisting of students of matching approach/perception of the learning environment. Presented in table 7.1 are the most consistent actions displayed by the students within the approach/perception categories and, in some cases, the infrequency of desired actions is also noted.

7.3 Qualitative evaluation of actions

Table 7.1 Students actions according to category

Approach/Perception	**Prevalent Actions**
PBL Deep/Constructively aligned	• *Explain their understanding* • *Leads group to understand and solve problem* • *Puts forward ideas* • *Disagrees with explanation* • *Answers tutor questions both directed and undirected* • *Asks questions of understanding nature of group* • *Discusses with group*
PBL Strategic/Problem solving	• *Putting forward ideas* • *Discusses with group* • *Calculating* • *Recording* • *Explains understanding infrequently* • *Disagrees with explanations infrequently* • *Answers tutor questions both directed and undirected*
PBL Surface/Participative	• *Questions – clarifying, no depth, goal of the problem* • *Only answer tutor directed questions* • *Watch* • *Work by self – Reading book* • *Discussing minimally* • *Completing learning issues*
PBL Strategic/Inappropriate	• *Explain understanding* • *Disagrees with explanation* • *Talk off topic* • *Ignore group members* • *Working by self* • *Ask questions (solution orientated)* • *Lead group to solve problem*

The tables of actions for each individual student can be found in Appendix H. Presented above are the most consistent actions displayed by each of the categories and, in some cases, the infrequency of desired actions is also noted.

PBL deep/constructively aligned

In contrast to the actions of the other approaches, those students in the *PBL deep/constructively aligned* category displayed their actions most consistently. A number of their actions could be interpreted as leading: delegating tasks, leading solution at the board, planning, directing the other members actions and leading are all displayed by the student. This leadership is in the form of making the group function but also in the capacity of pushing the group forward with solving and understanding the problem. Even asking questions of the group could be construed as a leading but also has more of effect on group understanding. This category/perception display a lot of actions that a problem-based tutor would consider contribute to understanding building for both the group and the student themselves: explaining their understanding of a concept, asking questions of an understanding nature of the group and disagreeing with other group members contributions with an explanation. This category/perception also asks the tutor questions and answers questions that are both directed to the group and themselves. They also contribute to the group through more functional methods such as contributing ideas and learning issues during the four columns process and they also complete their learning issues between sessions. To summarise this category/perception leads to the solution, promoted understanding, interacts with the tutor and contributes functionally as well.

PBL strategic/problem solving

Unlike the approach/perception *of PBL deep/constructively aligned* students, students adopting this approach/perception do not display their actions as consistently. The actions in Table 7.1 are the actions that were displayed most consistently for this approach/perception but were not necessarily displayed by students in every session. This is consistent with this approach/perception in that the motivational factors that affect their contribution are their prior knowledge of the problem, the topic of the problem and their perception of whether they can solve it. As these students moved from topic to topic, these motivational factors may have changed resulting in less consistent actions. The actions that are displayed consistently are: putting forward ideas to the solution, calculating, discussing with group members and discussing building ideas towards a solution. These students also spend a lot of time recording which is when a student stands at the board taking down information given to them from other group members or writing up their own ideas. It is similar to the *PBL deep/constructively aligned* action of leading the solution at a board in that they have the intent of pushing the group forward but what they are doing is a much more superficial attempt at solving the problem. One of the most obvious differences between the actions of the *PBL strategic/problem solving* and the *PBL deep/constructively aligned* is the lesser frequency at which actions that are understanding building occur. It is clear that these students do explain their understanding but that this does not always occur in a two hour session. Furthermore, there are a severe lack of instances where these students disagreed with the other members of their groups. This approach/perception answers tutor questions also, both directed and undirected (directed are questions asked to a specific student and undirected are questions that are asked to the group for anyone to answer).

PBL surface/participative

As would be expected from a category that involves students wanting to be perceived as participating there is a significant amount of superficial actions. These come in the form of questions of a clarifying nature or questions that have no substantial depth of understanding behind them. Most questions come in the form of “what the goal of the problem is?” which is again a clarification type of question, trying to find out what the point is behind the problem so they can solve it. They deal with the tutor aspect of the learning environment by ignoring their questions unless the questions are specifically directed at them. These students seem to interact with the learning environment through watching and being quiet and have a tendency to work by themselves in some capacity usually by reading a book.

They take a minimal part in group discussions often contributing only through agreements or again through asking questions of a clarifying nature.

Unlike the previous *PBL strategic*/*problem solving* categories, learning issues are more frequently completed for the second session. Again, it is the actions that are absent from these students but present in the *PBL deep/constructively aligned* and *PBL strategic*/*problem solving* students that clearly distinguishes the manifestation of this approach from the others. Where the *PBL strategic*/*problem solving* students explained their understanding sometimes, the *PBL surface/participative* category has a complete absence of students explaining their understanding and there is also a complete absence of disagreement with explanations. The absence of actions that are understanding orientated gives further evidence that these students are not aware of how to contribute to an active learning environment in a capacity that will result in them gaining an understanding.

However, there is some evidence that these students are evolving their approach over time with some students near the end of the mechanics section explaining understanding and disagreeing with explanations. These actions could be an indication of these students trying to change their approach and adapting to the learning environment and could be the positive influence of tutor feedback. Interestingly, there is also evidence of the surface nature of the *PBL surface/participative* category in the suggestions by the students towards finding the right formula during problem-based learning sessions. This is an action that is not condoned and this is made implicit through feedback and tutor interaction in problem-based learning sessions.

PBL strategic/inappropriate

The students in this approach/perception display a consistency in explaining their understanding and disagreeing with explanations of other students only seen in the *PBL deep* approach. There seems to be a strange balance between these understanding building actions and the negative actions that are probably a manifestation of their perception of the learning environment. The negative actions include such things as consistently talking off topic, ignoring members of the group, ignoring the tutor, working by themselves, not completing learning issues and a lack of discussion with the other group members. Their actions seem to be somewhat self-centred in nature and this self centred behaviour manifests itself by holding out explaining their understanding until the tutor is present, dismissively stating knowledge instead of their understanding when asked to explain something and then explaining the same understanding later when the tutor is present and slowing down the solution. On several occasions these students had to be directed to explain their understanding to the rest of the group. They have a tendency to lead the group at the board but again whereas a *PBL deep* student would engage in discussion and explaining understanding while at the board the emphasis of the *PBL strategic/inappropriate* student is on obtaining a solution as fast as possible. Also, they will do all the calculations of the solution to problem themselves. Off topic talking and distracting the group occurs generally under two circumstances. On the first day when they view all the pertinent information and learning issues that have been gathered and there is a knowledge gap to obtaining a solution and on the second day once a solution has been found. Overall students falling into this category participate in the learning environment in a self centred manner and often behave in a manner that would be construed as negative towards the group. But these students also often explain their understanding and disagree and confront their understanding with others which would have a positive effect on the development of their own understanding.

7.4 Discussion of actions in relation to approach and perception

In relation to the approaches/conceptions, the actions correlate with those described by both the phenomenographic categories and the descriptions the students provided in their interviews. Those who adopt a deep approach to their learning in the problem-based learning environment spend a lot of time on understanding orientated actions such as explaining their understanding and debating the group understanding and also in group discussion. In fact, the actions that are attributed to the deep approach in this study and the actions Chin (2003) attributes to a deep approach to laboratory work show striking similarities. For example, in the nature of explanations (Table 2.3) Chin's table describes students with a deep approach as having explanations that are "more detailed and elaborate, incorporating examples, analogies, real life experiences". The pattern continues when making comparisons with Chin's table in regards questions (Table 2.4) and Chin's table in regards approach to tasks (Table 2.6), with deep questions focusing on explanations and causes and approach to tasks being described as "talk/comments pitched at conceptual, analytical, and meta-conceptual, beyond observational and procedural levels". These elements of Chin's descriptions can be found in the *PBL deep/constructively aligned* approach perception.

Prior research could be not be found that described a strategic approach to a learning environment and which compared to the description of what a strategic approach entails by Richardson (1993), no real correlations could be found between actions and description of approach. This in truth is probably due to the two *PBL strategic* approaches having very different motivations than traditional strategic approaches. Those adopting a strategic approach spend time on understanding orientated actions but not with the frequency that the deep students do. Also the *PBL strategic/inappropriate* did contribute perhaps somewhat surprisingly through understanding orientated actions but their partaking in group discussion was limited. Otherwise, *strategic* students participated with an emphasis on solving the question with actions like calculating, putting forward ideas and recording (working at the board). This again is consistent with the description given in the approach which indicates that all the strategic students focus on solving the problem but will develop and contribute understanding when it is necessary for them to understand a concept or for the tutors to allow the group to move on with the solution.

The *PBL surface/participative* students correlate with the description of the approach and, in particular, with their perception of the learning environment. As the students perceive that they will be marked for participating and they want to be seen as participating, their actions are in the same vein. There is no deepness of understanding or attempted understanding in how they behave in the learning environment except in their work on the learning issues but even then, their complete understanding and explanation of them is limited but they could be still viewed as participating. Again this correlates with Chin's

(2003) descriptions of the actions of a surface approach especially in the areas of asking questions, approaches to tasks and nature of explanations. As indicated in the Chin research, the nature of explanations are unelaborated and the answers to questions are to basic information questions focused on factual recall. The approach to tasks is based on external information, for ideas and comments are limited to an observational or procedural nature. All of which correlates to the actions of the *PBL surface participative* students and so validates this studies attempts at observing the actions of students in a problem-based learning environment. Also, the lack of disagreement with explanation and explaining understanding by these students goes against one of the major tenets of problem-based learning which is formulation of a group understanding from cognitive conflict and agreement.

Frequency of actions or more particularly frequency of verbalisations has been used as a method of analysis in group work before (Jacques 2000) and although this analysis does share in this method, it is deeper. For example, experienced tutors use their value judgements to recognise whether a question is of a higher order. Comparisons between Conlin *et al.* (2007) group analysis of students behaviour are much more applicable than the frequency of verbalisation work mentioned above. Although Conlin *et al.* were examining the group of students as a whole and broke down their actions into frames (a frame being a set of expectations each participant brings into a situation that corresponds with their sense of what is going on), certain comparison between the frames used can be associated with the actions identified in this study. The reasoning behind not using a similar framing system is straight forward when you consider this study is trying to look at the individuals within the group but also from personal experience of working in and tutoring groups in problem-based learning, it is apparent that students would not always enter the same frame (i.e. have the same intention or contributing in the same manner). If you examine Conlin *et al's.* four frames of discussion, worksheet, socialising and receptive to teaching assistant, it is clear that all of these frames are represented in the actions found in this study.

Socialising and receptiveness to teaching assistant are the most obvious crossovers between studies in that actions are indicated for socialising in the capacity of talking off topic or distracting the group. Actions for receptiveness to teacher assistant are in the form of actions that relate to the tutor such as discussing with tutor, asking tutor questions and answering tutor questions directed and undirected. I believe the previous tutor-centric actions prove why the framing approach would not work in this case as through my qualitative judgement of the actions answering tutor questions directed and undirected are two distinctly different actions. A person answering only directed questions is not engaging with the tutor unless he/she is forced whereas a person answering tutor questions consistently could have many motives as indicated in the difference between the *PBL deep/constructively aligned* approach and the *PBL strategic/problem solving* approach. Returning to the Conlin *et al.* (2007) study, the other two frames can be seen in the above actions in the form of discussing and explaining understanding for the “discussion” frame and recording and calculating would be the “worksheet” frame. These parallels indicate that certain actions are inherent in a group learning environment.

The Tipping *et al.* (1995) research pointed out a discrepancy in the self reported behaviours of both students and tutors alike. The correlation between the categories of description for approaches to problem-based learning and the actions visible in the learning environment gives evidence that the students in this learning environment can report accurately on how they participated. Tipping *et al.*, however, go on to report that students showed no evidence of reflecting on any aspect of the groups’ behaviour nor did they have the awareness to correct behaviour that was not conducive to group performances. In relation to this study, there is evidence confirming this non-reflective behaviour from both the students taking the *PBL strategic* and *PBL surface* approaches. However, the students adopting the *PBL deep* approach demonstrate an awareness of the need to reflect on the group’s behaviour and their own effect on the group that is in keeping with their perception of the learning environment. As the following excerpt indicates:

Student: *Probably a little bit at the start trying to highjack the group and bring them down the road that I want to go down, so being a little bit of a dictator at the start. But I tried to change, I do think that I have gotten better at it, I try to* *listen to people as well rather than just disregarding what they say so yeah I have probably been better at that*

The *PBL strategic* and *PBL surface* students do not have this awareness and so do not demonstrate any self reflection or reflection of what occurred in group and how they could help to produce more effective group dynamics. Dolman (2001) also discussed the effect of students being assessed by tutors in problem-based learning groups and indicated that the students may feel required to demonstrate certain actions or behaviour that are artificial in order to impress the tutors. Evidence of this type of behaviour was found in two different types of capacities in this research study. Some of the *strategic* students indicated that they would attempt to reproduce actions indicated by feedback in order to impress the tutors and receive a higher mark on their feedback. As mentioned in the discussion for the perceptions of strategic and surface students this type of behaviour could be a result of their prior education background where students would be rewarded for such behaviour and indicate that these students are indeed in a transition due to the change in environment.

Interviewer: *When working on a problem were you always keeping in mind how to impress the tutor?*

Student: *Oh yes, 100% yes because again it was how I wanted to be perceived as well.*

Though this type of behaviour was not typical of these students and, in fact, when they did participate in the learning environment in this capacity they often found that it was not rewarded and so did not continue to do so. The other two approaches to the learning environment do not explicitly declare that they tried to act artificially or altered to their normal behaviour but the approaches and respective conceptions of the learning environment link to the behaviour they demonstrate in class. In the case of the deep approach, the students match their actions to those that are expected by the assessment scheme but that also will result in them developing an understanding and in a functioning group. On the other hand the *PBL surface* students match their actions and behaviour to their perceptions of the expectations of the tutors in that they want to be perceived as participating in the group. Neither of these instances are what would be described as artificial behaviour but it does show evidence of students adjusting their behaviour to match perceptions of tutor expectations.

This section identifies the actions of the different approaches to learning in the problem-based learning environment. However, in no way is the research study implying that if students adopt these actions that they will automatically be taking a deep approach to their learning. As was discussed previously adopting these actions will not change you meta-cognitively. An understanding of the need to adapt and develop their conception of understanding and reflect on how they learn, must take place in order for the indicated deep actions to result in a deep approach.

7.5 Chapter summary

The actions of students partaking in problem-based learning sessions were reviewed over the course of three problems and from this observation a description of the students' actions for each category of approach/perception was built in order to discover how the approaches to learning manifest in a problem-based learning environment. The results show a clear distinction between the actions of *PBL deep, PBL strategic* and *PBL surface* students with the exception that *PBL strategic/inappropriate* students displayed some of the key actions of the *PBL deep* approach but with obvious deviation in regards to how they treat the rest of the group. The actions were discussed in relation to the previous findings of approach/perception categories and in doing so created a more accurate portrayal of what having a certain approach to the problem-based learning environment actually means. The lack of understanding of building actions on the part of all of the approaches/perceptions except for the *PBL deep* was indicated and a link between this and students meta-cognition was made. The next chapter compares approach/perception and action to the students' scores on learning outcome evaluations.

CHAPTER 8

QUANTITATIVE EVALUATION OF CONCEPTUAL KNOWLEDGE AND QUANTITAIVE EVALUATION OF ASSESSMENT RESULTS

8.1 Introduction

This chapter introduces the first quantitative element of this research and uses quantitative data to indicate the level of the students' knowledge in order to measure the effects on the outcomes of the course (in the FMCE's case – conceptual understanding) that adopting one of the previously discovered approaches has on a student. Here the findings from the analysis of the data are presented and are then discussed in detail in relation to this study and relevant studies from the literature. As discussed earlier in Chapter 4, the aim of using the FMCE was to determine the students' normalised gain in conceptual knowledge between when they started the problem-based learning course and when they had finished being instructed in mechanics. The overall gain in conceptual knowledge as shown from the FMCE results for each individual student, individual approach and each individual approach/perception are presented although purely in an illustrative capacity, as there is not statistical significance due to the small numbers of students used in the study. A summary of the findings is then presented and then the results are discussed relative to prior research and in relation to the research presented so far in this thesis. Section 8.3 examines students' results on the two end of semester examinations which assessed both the students' conceptual understanding of the subjects they had learned and their ability to solve physics problems. The section ends with the students' assessment results from their continuous assessment in problem-based learning by the tutors.

8.2 Findings from FMCE

The pre-FMCE was administered on the induction day for the problem-based learning course and has been administered to all participating first year students each year, these students then undertook the problem-based learning course in mechanics. Once their mechanics modules were complete, I asked the same students to do the FMCE post-test. The following results presented are the individual normalised gain (Hake 1998) which takes account of the differences in the initial starting knowledge of students – as discussed in Chapter 4.

Table 8.1 shows the mean normalised gain for each of the individual students and the different approaches are indicated using the following colour scheme: red = *PBL deep*, green = *PBL strategic* and purple = *PBL surface*. For the purposes of clarity the normalised gain is shown to three significant figures.

Table 8.1 Research students mean normalised gain individual scores

Student name	Mean normalised gain
Student A	*-0.03*
Student B	*0.14*
Student C	*0.10*
Student D	*0.66*
Student E	*0.96*
Student F	*-0.03*
Student G	*-0.03*
Student H	*0.00*
Student I	*0.48*
Student J	*0.20*
Student K	*0.12*
Student L	*0.56*
Student M	*0.00*
Student N	*0.93*
Student O	*0.10*
Student P	*0.69*
Student Q	*0.34*
Student R	*0.00*
Student S	*0.09*
Student T	*0.12*

It is clear from the above table that the two students with the *PBL deep* approach to the learning environment have the highest normalised gains on the FMCE. It is also apparent that some of the *PBL strategic* students also have significantly high gains on the FMCE. The next table presents the FMCE scores as averages for each of the three separate approaches to the learning environment.

Table 8.2 Normalised gains for approaches to learning categories

Approach	Mean normalised gain
PBL deep	*0.945± 0.014*
PBL strategic	*0.327± 0.080*
PBL surface	*0.030± 0.024*

Table 8.2 clearly illustrates that the students adopting a deep approach to their learning in the problem-based learning environment achieve a much higher normalised gain than those adopting the other two approaches. Significantly though the students adopting the *PBL strategic* approach also have a significantly greater normalised gain than those adopting *PBL surface*. The above error in the final Table 8.3 of normalised gain scores illustrates the scores for each approach/perception category. The uncertainty shown is the standard deviation of the mean, $\sigma / \sqrt{N}$, also called the standard error, where σ is the standard deviation and N is the sample number. Due to the small number of students the error associated with such averages the above table is shown for purely illustrative purposes.

Table 8.3 Normalised gains for approaches/perceptions categories

Approach/perception	Mean normalised gain
PBL deep/constructively aligned	*0.945± 0.014*
PBL strategic/problem solving	*0.330± 0.081*
PBL surface/participative	*0.030± 0.010*
PBL strategic/inappropriate	*0.324± 0.090*

Table 8.3 shows that there appears to be no difference between the two different *PBL strategic* perceptions with the *PBL strategic/problem solving* and *PBL strategic/inappropriate* having practically the same normalised gains. One interesting conclusion that can be taken from the above results is that having the perception that the learning environment is inappropriate does not have a knock on negative effect on students development of conceptual understanding.

8.3 End of semester exams

The results for the students' two end-of-year assessments are illustrated below. It is important to note that while these assessments had conceptual elements and involved the application of the conceptual knowledge to similar situations to that of the problem-based learning problems, the emphasis of the end-of-year assessment was more knowledge and the application of that knowledge. The individual results for each of the students are presented below in some cases n/a is indicated in the result and this for a student who did not sit the exam. The semester one exam was on mechanics and optics while the semester two exam was on heat, electricity and modern physics.

Table 8.4 End of semester assessments for each student

Student name	Semester one examination	Semester two examination
Student A	*49.2*	*46.0*
Student B	*60.8*	*64.0*
Student C	*63.1*	*40.0*
Student D	*75.5*	*79.0*
Student E	*N/a*	*68.0*
Student F	*26.7*	*17.0*
Student G	*24.2*	*51.0*
Student H	*22.5*	*41.0*
Student I	*47.5*	*54.0*
Student J	*38.3*	*42.0*
Student K	*41.0*	*50.0*
Student L	*42.0*	*80.0*
Student M	*65.0*	*89.0*
Student N	*72.0*	*95.0*
Student O	*63.0*	*44.0*
Student P	*59.0*	*80.0*
Student Q	*57.0*	*83.0*
Student R	*57.0*	*81.0*
Student S	*19.0*	*28.0*
Student T	*16.0*	*45.0*

There is not the same initial clarity to the trend of the results in Table 8.4 that the FMCE results displayed but after Table 8.5 the trends should become clearer.

Table 8.5 End of semester results for approaches to learning

Approach	Average semester one examination score	Average semester two examination score
PBL deep	*72.0±N/a*	*81.5±13.5*
PBL strategic	*57.1±03.7*	*65.5±06.0*
PBL surface	*31.9±05.3*	*44.9±06.6*

Again the results above have no statistical significance but do continue to illustrate the trend from the FMCE results of *deep>strategic>surface* in score on the test. So students who are adopting a deep approach to their learning in the problem-based learning environment do better on the end of year assessments. This would again be expected in a course that is constructively aligned for students to obtain a conceptual understanding and reward a deep approach. If *strategic* or *surface* had achieved higher grades it would have been more of a testament to the course not being constructively aligned rather than the deep approach not resulting in good grades. The next table breaks down the assessment results for each *approach/perception*.

Table 8.6 End of semester results for approach/perception

Approach/perception	Average semester one examination score	Average semester two examination score
PBL deep/awareness	*72.0±N/a*	*81.5±13.5*
PBL strategic/problem solving	*60.2±03.1*	*65.6±07.4*
PBL surface/participative	*31.9±05.3*	*44.9±06.6*
PBL strategic/inappropriate	*54.1±04.0*	*64.2±08.0*

It was already apparent that there was a perceived difference between the *deep/strategic/surface* approaches and the above table does not exhibit any new clear differences between the different perceptions of the learning environment. The two *strategic* perceptions do not show any significant differences between their end of semester exams but again this does demonstrate that have the perception that the learning environment is in appropriate does not seem to effect these students on the end of semester exams.

8.4 Overall process mark for problem-based learning semesters

The results for the overall process mark for the problem-based learning semesters is displayed below. The overall process mark refers to the average mark of the marks out of ten the students would receive as part of their feedback and the mark given for reports they completed for problem-based learning problems. The feedback mark makes up 85% of the process mark and the reports make up the rest of the 15% percent. Again as before the individual scores will be presented first which are displayed in Table 8.7.

Table 8.7 Individual problem-based learning process marks for semester 1 and 2

Student name	Semester one problem-based learning overall process mark	Semester two problem-based learning overall process mark
Student A	*58.6*	*62.5*
Student B	*68.6*	*63.8*
Student C	*69.3*	*63.1*
Student D	*58.6*	*72.0*
Student E	*47.1*	*62.1*
Student F	*59.3*	*63.1*
Student G	*67.1*	*49.4*
Student H	*67.1*	*61.9*
Student I	*58.6*	*64.4*
Student J	*67.1*	*63.1*
Student K	*44.2*	*70.0*
Student L	*42.9*	*43.4*
Student M	*41.6*	*67.5*
Student N	*44.6*	*66.3*
Student O	*38.9*	*51.3*
Student P	*43.3*	*50.0*
Student Q	*36.7*	*43.8*
Student R	*42.0*	*73.8*
Student S	*30.6*	*58.8*
Student T	*36.7*	*70.0*

Again the results from the individual results do not display any instant trend but again in Table 8.8 we will examine the results for each approach.

Table 8.8 Process marks for semester 1 and 2 for approaches to learning

Approach	Average semester one problem-based learning mark	Average semester two problem-based learning mark
PBL deep	*45.9±01.2*	*64.2±02.0*
PBL strategic	*52.7±04.3*	*58.2±03.2*
PBL surface	*50.7±05.0*	*63.7±02.7*

As was previously discussed in regards to the numbers of students involved in the problem the averages displayed in the table below cannot be taken as being statistically significant. But in regards to the dispersion between the results, there is far much less spread of marks between the three approaches and for the first time the *deep* approach is not the average highest result.

Table 8.9 Process marks for semester 1 and 2 for approaches/perceptions

Approach/perception	Average semester one problem-based learning mark	Average semester two problem-based learning mark
PBL deep/constructively aligned	*45.9±01.2*	*64.2±02.0*
PBL strategic/problem solving	*49.9±05.5*	*60.8±04.4*
PBL surface/participative	*50.7±05.0*	*63.7±02.7*
PBL strategic/inappropriate	*55.2±06.7*	*55.7±04.9*

When broken down into the respective approaches/perceptions again the spread is not as wide as the previous assessments with the two most interesting results being that in semester one the *PBL deep/constructively aligned* is the lowest scoring and there seems to be a significantly greater climb in grade by all of the approaches except for the *PBL strategic/inappropriate* between semester one and semester two.

8.5 Summary

The previous section illustrated the results of three elements of the expected outcomes of a problem-based learning course. The first element being a conceptual understanding evaluation that determined the students' gains in conceptual understanding over a period of time. The second element being the students' assessment results for their end of year exams and the third being their problem-based learning continuous assessment marks. This combination of assessments and evaluations assessed these students on their conceptual understanding, problem solving ability and their ability to work in a group. The next section discusses any trends or correlations in the findings and compare to previous research in the area of approaches to learning and the resulting effect on assessment outcomes.

8.6 Discussion of findings from FMCE and Assessments

Due to the statistical insignificance of the results as a product of the small number of students included in the study, it is difficult to discuss any apparent correlations or similarities in the results besides pointing to the differences between the different approaches within the learning environment. In essence, the results of the assessments and evaluations are included in the thesis to illustrate whether the different approaches would result in differing amounts of conceptual development and differing levels of achievement on course outcomes. The above results indicate that the different approaches students adopt to their learning in the problem-based learning environment will result in different levels of achievement on conceptual evaluations and end of semester exams but not for the continuous assessment mark from the problem-based learning sessions. This combination of assessments indicated a trend in which students adopting a *PBL deep* approach achieved superior results on all of the assessments and evaluations compared to the *PBL strategic* students and in turn the *PBL strategic* students achieved superior results compared to the *PBL surface* students on assessments and evaluations except for the continuous assessment mark. Regarding the continuous assessment mark there are a number of reasons why the results do not follow the same trend as the FMCE and examination results. The discrepancy in the results could be a result of the tutor in the problem-based learning classes being a roaming one. Meaning that they move from group to group and so their assessment is based only on the time spent observing the students which could result in them missing elements of a student’s contribution. Another reason could be the tutor having different expectations of different students and assess accordingly. This is probably more influential in the second semester of problem-based learning as by that stage the tutors have become familiar with the students and their abilities. Another reason for the discrepancy may be that the continuous assessment mark is often used as a motivator with positive behaviour rewarded and negative behaviour punished (behaviourist theory). The final reason may be that the tutor may not be inclined to give less than 40% for a continuous assessment mark when the student continuously turns up and participates.

According to Walsh (2009), the average gain for a student in a traditionally taught physics course in DIT is 0.0048 and the average gain for students taught physics through problem-based learning is 0.2264. When compared to the gains attributed to the approaches in this study, it is apparent that both the *PBL surface* and *PBL deep* approaches are producing larger than average gains. It displays that although the *PBL surface* gain is poor, it is still better than the average score for a traditionally taught student. In a report by California Polytechnic (http://www.phystec.org/institutions/calpoly-obispo/assessment.php) in which they examined students gains in conceptual knowledge over a three year period and two different teaching methods the following results were obtained.

Table 8.10 Comparison of three approaches to introductory mechanics FMCE scores – California Polytechnic Website

Year	Course	Pre	Post	Gain	Number of students
1998-2001	*Studio Physics*	*31.9*	*72.1*	*0.60*	*966*
1998-2001	*Traditional Physics*	*35.5*	*53.3*	*0.30*	*300*

The studio physics course environment is comparable to the problem-based learning environment in that it involves students working in groups either completing laboratory exercises or other physics group orientated activities. Purely for illustrative purposes, as there is no statistical significance in comparing the 2 *PBL deep* students to 966 studio physics students, it can be seen that the *PBL deep* students gain of .94 is extraordinarily larger than that of the studio physics average gain of .60. Cummings *et al.* (1999) also did a similar study assessing pedagogical developments using both the FCI and FMCE and found that with students in a studio physics learning environment in which cooperative group problem solving was used the gain was found to be 0.36 on the FMCE. Again this illustrates how well the *PBL deep* approach students are doing on the conceptual evaluation but also demonstrates that comparatively the *PBL strategic* students are also achieving respectable gains in conceptual understanding.

8.7 Discussion of FMCE and assessments with approaches/perceptions/actions

As was indicated in the literature review, there is a wide range of studies that present a positive relationship between adopting a deep approach and achieving high scores on learning outcomes: (Biggs 1985, 1987a; Marton & Saljo 1984, Prosser & Millar 1989, Gibbs 1992 and Watkins & Hattie 1981) and those with deep approaches/deep perceptions also achieved highly on learning outcomes (Meyer *et al.* 1990 and Prosser & Trigwell 1999). From the above demonstrated assessments and evaluations, it is illustrated that the deep students within this study on average achieved the highest scores and, therefore, the research shows agreement with this previous body of work. More importantly, it indicates as Van Rossum & Schenk (1984) postulated, that students who adopt a deep approach would be expected to achieve a high quality outcome in an environment designed to encourage a deep approach.

In concurrence with this finding and as was noted above, the *PBL surface* approach students in the problem-based learning environment are performing poorly on all of the assessment criteria and evaluations except for the problem-based learning process mark. This again is in agreement with other approaches to learning research as Baeten *et al.* (2008) which indicates that a surface approach can be a predictor for poor performance on assessments. Interestingly though, the *PBL surface* approach results, show an alignment with those of Prosser & Trigwell (1999) and Hazel *et al.* (2002) which found that disintegrated (perception of deep environment but surface approach) learning orchestrations (relationship between approach/perception/learning outcomes) resulted in poor achievement on learning outcomes. This indicates that the *PBL surface* approach is a disintegrated learning orchestration.

In truth this level of performance by surface students in a learning environment that encourages a deep approach to learning is as expected and it would be surprising if those adopting a surface approach were achieving in a deep orientated learning environment. The Ellis *et al.* (2007) paper that has been previously discussed in relation to the approaches to learning, also correlated their approaches to the student performance and found that the deep approach students performed at higher levels than that of strategic and surface. They also found no correlation between a strategic approach and high performance. The same cannot be said for this study, with each approach being associated with a different level of performance. Other studies such as Beckwith 1991; Reid *et al.* 2007 and Gijbels *et al.* 2005 have all demonstrated different levels of achievement for deep/strategic/surface approaches to learning similar to those demonstrated in this project.

There are multiple reasons why different levels of achievement on conceptual evaluations and end of semester exams would occur for the different approaches. The most obvious is the different conceptions of conceptual understanding and the different emphasis the approaches place on understanding. The physics problem-based learning course emphasises conceptual understanding as an important part of learning and assessment and it has already been illustrated that the deep/strategic/surface approaches all emphasise understanding in their approach at different levels in the problem-based learning environment. The same would not be true for a pharmacy course which is the environment in which the Ellis et al paper is set with their intention more inclined towards producing competent practitioners.

CHAPTER 9

Student Profiles

The following data that is presented are not research findings but instead it is data which was collected which will be used to put the findings in context in Chapter 10. It gives some more details on the individual students who took part in the study in regards to their age, prior education, attitudes to physics, FMCE prior knowledge and approaches to examinations.

9.1 Prior physics and age of students

Table 9.1 Prior physics and age of students

Student name	Prior physics	Age
Student A	*Leaving Certificate B3 Higher Level*	*17*
Student B	*Leaving Certificate B3 Higher Level*	*18*
Student C	*Leaving Certificate C3 Higher Level*	*19*
Student D	*Leaving Certificate C1 Higher Level*	*18*
Student E	*Leaving Certificate D2 Higher Level*	*30*
Student F	*No prior physics*	*18*
Student G	*No prior physics*	*17*
Student H	*No prior physics*	*18*
Student I	*Secondary school equivalency*	*23*
Student J	*One year college level*	*22*
Student K	*Leaving certificate D3 Higher Level*	*17*
Student L	*One year college level*	*22*
Student M	*Leaving Certificate C3 Higher Level*	*18*
Student N	*Leaving Certificate C2 Higher Level*	*29*
Student O	*Leaving Certificate C2 Higher Level*	*18*
Student P	*Leaving Certificate B2 Higher Level*	*22*
Student Q	*Leaving Certificate B2 Higher Level*	*18*
Student R	*Leaving Certificate B1 Higher Level*	*18*
Student S	*No prior physics*	*19*
Student T	*Leaving Certificate B3 Ordinary Level*	*18*

There are two main areas of interests from the background information table presented above. The first of which is the age of the students adopting the deep approach to learning in the problem-based learning environment, with both students being what would be considered mature students. Does this mean then, that only mature students have the ability to adopt a deep approach to their learning or does it mean that they can adapt to the learning environment quicker as they are the longest away from the second level system? As has already been indicated, the majority of the students would have come from the goal achieving surface rewarding second level system of the Leaving Certificate and may have trouble adapting when introduced to the problem-based learning environment and this result may indicate the difficulty students have adapting. This may be indicative of the fact that the research is not just set in a problem-based learning environment but specifically an early stage problem-based learning environment. It would be interesting to repeat the study of students doing problem-based learning in later years in college. The other area of interest is that half of the students that adopt the *surface* approach, have no prior physics experience when starting the course. This is in contrast to the other two approaches in which all of the students that have adopted them have prior physics knowledge in some capacity. These two areas of interest are taken up in Chapter 10 which relates and discusses all information gathered on the students with the results of this research study, to give a detailed picture of approaches to learning in a problem-based learning environment.

9.2 CLASS

The purpose behind the CLASS survey is to measure students' attitudes and beliefs pertaining to physics and was given to the participants before they took the problem-based learning mechanics module. The survey measures the percentage agreement students have with experts on statements relating to various aspects of physics and studying physics. The results are then broken down into overall agreement and several other categories not all of which have been included in the tables below. One of the students was absent for the survey and so his responses have been marked N/a.

Table 9.2 CLASS results for statistically significant categories

Category	Overall %	Conceptual understanding %	Conceptual understanding applied %
Student A	*72*	*66*	*57*
Student B	*52*	*16*	*14*
Student C	*61*	*50*	*42*
Student D	*86*	*66*	*57*
Student E	*94*	*100*	*100*
Student F	*61*	*33*	*14*
Student G	*36*	*0*	*14*
Student H	*63*	*33*	*14*
Student I	*58*	*66*	*57*
Student J	*80*	*66*	*57*
Student K	*N/a*	*N/a*	*N/a*
Student L	*75*	*100*	*85*
Student M	*80*	*66*	*85*
Student N	*75*	*83*	*57*
Student O	*50*	*33*	*28*
Student P	*50*	*33*	*42*
Student Q	*58*	*33*	*28*
Student R	*77*	*73*	*71*
Student S	*63*	*50*	*28*
Student T	*63*	*83*	*57*

Table 9.3 CLASS results for statistically significant categories broken into approaches

Category/Approach	Overall %	Conceptual understanding %	Conceptual understanding applied %
PBL deep	*84±9*	*91±8*	*78±21*
PBL Strategic	*65±4*	*52±8*	*49±7*
PBL Surface	*62±5*	*48±11*	*36±9*

Table 9.4 CLASS results for statistically significant categories broken into approach/perception

Category/Approach	Overall %	Conceptual understanding %	Conceptual understanding applied %
PBL Deep/constructively aligned	*84±9*	*91±8*	*78±21*
PBL Strategic/problem solving	*69±8*	*53±14*	*54±9*
PBL Surface/participative	*62±5*	*48±11*	*36±9*
PBL Strategic/inappropriate	*60±4*	*53±14*	*45±12*

The results that are demonstrated in the above tables are all the percentage of responses for which the students or student in the case of the first table agrees with the experts' view of the statements presented in the CLASS survey. So for example, from Table 9.4 the *PBL deep* students agreed with 84% of the experts view of responses to the statements. There are a few points of interest from the tables above. However, due to the significant error or uncertainity associated with the CLASS results, these are again mainly used to further illustrate results that we have seen already. For example the *PBL deep* students appear to have a very expert view and attitude towards physics, scoring highest in the overall percentage agreement. Interestingly and corresponding to the previous results from the FMCE, these students also have the highest percentage agreement with the experts in both conceptual understanding categories especially in the conceptual understanding category.

Another result that may be illustrative of and explain previous results presented in this thesis is the *PBL strategic/inappropriate* approach/intention getting the lowest score on agreement with the experts. Their lower percentage agreement with experts attitudes to physics and opinions on physics, could go some way towards accounting for their attitude of aversion to the problem-based physics course. However, the difference is small and so no weight can be given to this argument. In the conceptual understanding applied category, the three different approaches to the learning environment display a similar pattern of attitude towards conceptual understanding than was indicated in both the description of the approaches and in the FMCE results. Again this is not unexpected as three different conceptions of understanding have been indicated in the approaches to learning descriptions and I indicated that the conceptions were more evolved than each other. The results from the CLASS would seem to indicate that these different evolutions of conceptions seem to relate to an experts conception of understanding to some extent.

9.3 Prior Knowledge – FMCE Pre

Table 9.5 Average FMCE pre scores for each approach

Approach	Average pre-FMCE score
PBL deep	*39.4*±15.2
PBL strategic	*17.9*±03.5
PBL surface	*08.7*±01.5

Table 9.5 illustrates that students have different levels of conceptual mechanics knowledge on entering the problem-based learning environment. This would seem to indicate that the level of knowledge on entering the course correlates with the gain the students will achieve after instruction. However, having higher pre scores could also indicate that students see the world in a more Newtonian way and hence have a more sophisticated conception of understanding in physics as indicated in the approaches to learning categories. The fact that the gain score is the total maximum gain and takes into account the pre score would add some weight to this argument.

9.4 Approach and perception of physics end of semester exams

As discussed in section 4.5, the students were questioned about their approaches to, and perceptions of, the end of semester exams in the interviews which took place after the students had taken their first set of semester exams. This was not included in the phenomenographic analysis of the learning environment as I felt that the exams and problem-based learning sessions were two separate entities in regard to perceiving them. Table 9.6 presents the approach and perception of the end of semester exams that the majority of students for each of the approaches/perceptions. This is in no way should be confused with the phenomenographic methodology employed to find the approaches to learning in and perceptions of the problem-based learning environment. It is instead merely an indication of how the students in each category typically responded to questions about what they thought the physics exam was assessing and how they prepared for it.

Table 9.6 Approach and perception of end of semester exams

Approach/Perception	Perception of what exam was assessing	Preparation approach to end of semester exam
PBL Deep/constructively aligned	Understanding and problem solving skills	Obtain fundamental understanding and apply to pass exam papers
PBL Strategic/problem solving	Understanding and problem solving skills	Seek understanding and solve example questions
PBL Surface/participative	Understanding and solutions	Memorise method of solution
PBL Strategic/inappropriate	Understanding and problem solving skills	Didn't prepare

The approaches and perceptions of the end of semester exams were found by examining the responses of students to questions about the end of semester exams and then attributing a general consensus to the answers for each of the approaches/perceptions. These perceptions and preparation approach have been mentioned previously and are discussed again in Chapter 10.

9.5 Chapter summary

This chapter presented some background data on the profile of the students in the form of their age, prior physics schooling, attitudes to physics questionnaire responses and FMCE pre results. It indicated that the two mature students were the two students who adopted the *PBL deep* approach and that FMCE pre scores seem to be predictive of FMCE gain in this learning environment. The attitude to physics scores gave further evidence to the different levels of conception of understanding that are inherent in the approaches to learning. Chapter 10 takes all of the results presented so far and discuss for one final time the interrelationships between all of the facets of this research.

CHAPTER 10

DISCUSSION AND CORELLATION OF ALL COLLECTED DATA

10.1 Discussion and correlation of all data collected

At this stage of the analysis it should have become quite apparent that although unintentional, this research project is in many ways a case study of students learning in the problem-based learning environment during their first semester of problem-based learning. The following three sections will relate all of the findings and information gathered in this research study to illustrate in detail the three approaches to learning found in this study and their relationship to learning outcomes.

10.2 PBL Deep approach

Firstly, like all of the approaches to learning found in this research study the approaches are intrinsically linked to the conception of understanding that is encompassed in the approach. The *PBL deep* approach has a very sophisticated conception of understanding that entails understanding not just the concept itself but also the interconnections between concepts and the relationships between the different facets of the concept. This evolved conception of understanding appears to be confirmed by the *PBL deep* students' results on the CLASS survey, with a high agreement on the conceptual understanding categories within the survey. This conception of understanding is essential to this approach in this problem-based learning environment as when it comes to actions and motivations that involve understanding or explaining understanding within the environment, students are influenced by the conception of understanding. That is to say that if deep students explain their understanding, they do so in the multi faceted and linked manner that they believe is necessary to truly understand something.

Given this conception of understanding, it is not surprising that the emphasis of the *PBL deep* approach is to understand the material that students are confronted with in the problem-based learning environment. The approach as described by the students, focuses on gaining an understanding but not just an individual understanding, as these students see the value in making sure the group as a whole gains an understanding. They describe discussing and explaining their understanding to the group and reflecting on others' explanations. Approaching their learning in the problem-based learning environment in this way will also often result in them taking a leadership role but again with the focus firmly on personal and group understanding. The results from the observation analysis confirm that the above description of the approach is a very accurate portrayal of how these students participate in the problem-based learning environment. Discussing, disagreement with explanation, explaining understanding and leading (for understanding) are displayed as common occurrences by these students. In regard to how this approach manifests itself in relation to exam preparation, these students believe that in order to do well in their exams, they must gain a fundamental understanding of the material.

The *PBL deep* approach to problem-based learning and the assessments within the course, result in these students achieving higher grades than the other approaches to learning within the problem-based learning environment. Although the results displayed were obviously not statistically significant, they did illustrate that these students develop greater gains in conceptual understanding, achieved higher grades on all assessments except for the problem-based learning process mark. These results are in agreement with much of the prior research on the correlation between deep approaches and achievement within environments. It cannot be ignored that the two students who were indicated to have taken a deep approach were both mature students and that their previous life experiences may have developed them meta-cognitively which resulted in them approaching the learning environment in the manner they did or, as indicated in prior discussions, the time away from the secondary school environment of competitive assessment and encouraged surface approaches has resulted in an easier transition to the deep problem-based learning environment.

Given the limited number of students within the study, it is not possible to investigate this result in any more detail but it would be an interesting avenue of research for further work. However, the main indicator for taking a deep approach in a physics problem-based learning environment would seem to be a student's conception of understanding and although this may have evolved with age, it is not something that is limited to age and could be developed by younger students. Anecdotally, when discussing the findings with the problem-based tutors, they identified past students who they believe would have fallen into the *PBL deep* approach and who were not mature students. Correspondingly, I believe that one of the students who was interviewed as part of the pilot interview process, also would have fallen into the *PBL deep* approach and that student would have come straight from the secondary level and would not be considered a mature student.

So far, the results discussed above have depicted a very traditional deep approach to learning that has been found in many environments. There is, however, a major difference that could be a result of the learning environment itself. One key aspect of all traditional deep approaches to learning is that the students have an intrinsic motivation to understand the material. Although I believe that the deep students within the problem based learning environment are intrinsically motivated to understand the material, this was not forthcoming or prevalently displayed in the interview process. Instead, these students indicate that they are aware that the tutors are expecting them to understand. They are aware that they are assessed on understanding, that the end of year assessments will assess understanding and that the learning environment is constructed for them to understand the material. It is this awareness of all these factors that motivate the students to attempt to get an understanding. That is not to say that the intrinsic motivation that is part of a traditional deep approach is missing in the *PBL deep* students. The CLASS results would seem to indicate that they have a high personal interest in physics as indicated by their overall agreement with experts. Their perception of the learning environment indicates that they are positive both towards physics and problem-based learning. However, at no point in the interviews, did they or any student indicate that they try to understand because it is in their nature to do so.

Therefore, it is the combination of the developed conception of understanding and the awareness that the environment requires an understanding that leads to this deep approach and not intrinsic motivation. I believe that these students show too many correlations to the traditional deep approach as described by Leung & Kember (2003) to be considered to have adopted a traditional strategic approach. However, their emphasis on assessment would seem to indicate a strategic type approach. My view is that a traditional strategic learner placed in the DIT physics problem-based learning environment, would never have the opportunity to choose to take a surface approach to a problem if they are matching their approach to the assessment. The assessment emphasises a deep understanding too strongly for a traditional strategic student to adopt a surface approach. Again, this mixture of elements from traditional deep and traditional strategic could be the manifestation of the adjustment of these students to the problem-based learning environment and it would interesting to investigate the approaches to learning of these students as they continue their studies through problem-based learning. As Duke *et al.* 1998 indicated there is a shift in approach towards a deep approach after prolonged exposure to problem-based learning.

10.3 PBL Strategic Approach

Probably the most complicated of the approaches discovered is the *PBL strategic*, which encompasses one intention but is a result of two distinct different perceptions. Again, like the *PBL deep* approach summary, the discussion of the *PBL strategic* approach has to start with the students' conception of understanding. These students' view of understanding is based around application. For them, to understand a concept is to use it again perhaps in different situations or to be able to explain the concept or use it to answer questions. There is always a purpose or use for understanding a concept in this approach to the problem-based learning environment. Like the previous discussion on the *PBL deep* approach, this conception of understanding has an effect on the manner in which these students approach the learning environment. So, when a student who approaches the learning environment in this manner describes their understanding or disagrees with their fellow students, their explanations come in the form of the application of a concept and not in the multifaceted manner manifested by the deep students.

The singular intention behind the *PBL strategic* approach is to solve the problem-based learning problem, preferably as quickly as possible. They are aware that they should be understanding the material but choose to ignore this and focus on solving the problem. This focus often comes in the form of finding examples of problems that can be applied to solving the problem or finding the right equation. That is not to say that these students ignore understanding altogether, instead students adopting this approach will only explain, discuss and disagree with their understanding if it is a necessary step in reaching the solution. This singular intention to solve the problem is the main difference between the *PBL strategic* approach and a traditional strategic approach. The emphasis in a traditional strategic approach is on the intention of doing what is needed to do well on assessments and generally do well in the course. The *PBL strategic* students ignore the assessment criteria and instead focus on solving the problem often to the detriment of doing well in regard to assessment. The interesting result in relation to the observation findings, is when comparing the approach to the manifestation of the approach, the amount of time these students spend contributing and confronting their understanding. The learning environment often forces them to contribute in a deep manner that they would otherwise ignore. Again, as discussed previously, this approach could be the manifestation of these students adjusting to the problem-based learning environment. This manifestation would indicate that their primary focus has moved on from their previous learning environment of secondary school in which, judging by their physics Leaving Certificate scores, they were quite successful. If this study was repeated in the second semester of the problem-based learning course it would be interesting to see if their approach altered to become of a deeper nature and be understanding focused or if they continued to focus on seeking a solution.

One of the main features of this approach to the learning environment is that it is backed by two different motivations. These have been described as “inappropriate” and “problem solving”. Although the “inappropriate” perception of the learning environment has the intention of solving a problem, this is only because this is the only part of the course and assessment criteria with which they reconcile their interests. The “inappropriate” students have the perception that the learning environment is too focused on group work and believe the assessment criteria puts too much emphasis on this aspect. Again, this could be a manifestation of resistance to adapting to a group learning environment because these students have been successful in the previous surface solution driven learning environment.

These students also indicate that working with group members is the most annoying aspect of the learning environment and that they would prefer to work alone. In their descriptions of their perceptions, they maintain that they have a high interest in physics and yet their CLASS results would seem to indicate a misalignment between these students’ attitudes and the perceptions of physics that the experts have. The “inappropriate” perception also seems to feature a certain lack of motivation, with students who have this perception indicating that the learning environment involved too much work and that they did not prepare for assessments. They also view tutors as being unhelpful and contributing very little to the problem solving process. This again would be expected from students who did well in an environment in which information was transmitted to them and they regurgitated it.

All of the *PBL strategic/inappropriate* students have prior physics experience and the “inappropriate” students especially have a tendency to lead the groups they are in towards a solution but, in the process, end up having to disagree with group members and explaining their understanding and so they have to confront and explain their understanding more frequently than other strategic students. Again, this is the learning environment forcing the students to take a deep approach even though it as far from their intention. However, as much as these students participate in a non-intentional positive way, they also participate in intentionally negative ways as the observation results demonstrated, for example, working by themselves, ignoring group members and talking off topic. In regard to assessments, there is not much difference between the “inappropriate” and “problem solving” perceptions of the learning environment. As indicated previously, students with the “inappropriate” perception scored lower on the overall category than the other strategic approach students taking the CLASS which indicates a lower expert aligned attitude and perception of physics.

On the other hand, students adopting the “problem solving” perception of the learning environment have no strong negative feelings towards problem-based learning or physics, indicating that they like both. Like students with the “inappropriate” perception of the learning environment, the emphasis is still on solving the problem rather than doing well on the assessment scheme and this is the source of all their motivation. So much so, that the students indicate both in the interviews and from the observation data that they will stop contributing to the problem solving process if they believe they have found a viable solution to the problem. Students with a ‘provlem solving’ perception have a mixed view of the role that tutors play in the process, with the students indicating they (tutors) have a positive effect, help them to understand the material and motivate them. However, on occasions these students find them frustrating and uncooperative to the students goal of solving the problem. Where the “inappropriate” students where only motivated by solving the problem as it was the only element of the problem-based learning environment that they accepted and they often lost motivation because of their dislike of interacting with the group. The motivation of students with “problem solving” perceptions is based in their perception of whether they can solve the problem. So they ask themselves do they have enough prior knowledge to solve the problem or do they think they can solve the problem and if the answer is yes they will be motivated but if the answer is no they will become as lacking in motivation as the “inappropriate” students.

Another difference of the ‘problem solving’ perception from the ‘inappropriate’ perception is that these students do not perceive the learning environment as involving too much work and they also prepare for assessments by going over notes that they made in class and by setting out example questions. In regard to assessment, they see the assessment criteria as putting too much emphasis on group work aspects of the course. However, this does not influence them except in so far as they are aware that they will get marks for group orientated work but nevertheless, choose to concentrate on solving the problem. In regard to the assessment marks and the FMCE, these students achieve the same grades as the students with the same approach but different perception on the FMCE and on the other assessments and unlike the “inappropriate” perception students, they progress their problem-based learning assessment mark between semesters. Their attitudes and perceptions of physics as measured by the CLASS also seem to align more with the experts than those of “inappropriate” students. The way they participate also seems to manifest itself in the problem-based learning sessions in a slightly different way than the “inappropriate” perception students, in that they do not lead the group as much and so have a tendency to not confront their understanding and explain their understanding quite as much as student with an “inappropriate” perception. However, on the other hand, they do not participate in the negative ways in which the “inappropriate” students do.

Overall, when correlating the *PBL strategic* approach with the other approaches found in this study, the *PBL strategic* students are in-between the *PBL deep* and *PBL surface* in regard to assessments and conceptual assessment scores. They do significantly better than the ‘*surface*’ students in the conceptual evaluation because of their more evolved sense of what understanding is and because they use this more evolved understanding more frequently in the problem-based learning sessions because they are forced to do so by the learning environment. They also do better on the end of semester assessments and other continuous assessments that come in form of examinations, than do the *PBL surface* students but perform poorer than students with a *PBL deep* approach. The reasoning behind this is probably the evolved sense of understanding and more frequent use of that understanding than students with the *PBL surface* approach. This evolved sense of understanding may be because having prior physics experience is more likely to result in a more evolved sense of what it means to understand something in physics than a student who had never studied the subject. The *strategic* students have the same average age as those with a *PBL surface* approach but are obviously much younger than the mature students taking the *deep* approach. In regard to the CLASS, *strategic* students seem to exhibit a greater agreement with the experts in the conceptual understanding categories and increased overall agreement than that of the *PBL surface* students but less than the *PBL deep* approach in most of the categories.

10.4 PBL Surface Approach

As with all of the approaches discussed in this section, we first have to start with the students who adopt the '*surface*' conception of understanding. To adopt this approach is to have a conception of understanding that means that you can explain a concept to someone else so that they can understand it but also that you always remember the concept yourself. Although this is not necessarily a bad conception of understanding, the limitations of what it truly means become clearer when comparing this conception with the students' method of participation within the problem-based learning environment. The only occasions when these students share their understanding in the problem-based learning environment, is when they discuss their prior knowledge or the work that they have carried out on learning issues and their understanding comes in a form similar to text book definitions. There is more evidence of understanding equalling repetition when it comes to their preparation for an examination which they perceive as testing their understanding. They memorise methods of solutions from the original problem-based learning problems in the hope that they can replicate the knowledge in the examination and it matches the questions asked. So having a conception of understanding that is based on repetition makes the students adopting this approach poorly equipped to deal with an active learning environment which concentrates on developing a more expert understanding of the physics concepts.

As with the previous discussion of the approaches, this conception of understanding influences both how these students approach and participate in problem-based learning. There are two main intentions behind the *PBL surface* approach: to understand and to solve the problem which is a combination of the *PBL deep* and the *PBL strategic* approaches. These intentions are a manifestation of these students' perception of the learning environment in that they perceive that the tutors expect them to gain an understanding and to solve the problems. These two different perceptions of the learning environment (understand/solve problem) could be indicative of the students having disintegrated learning orchestrations but having disintegrated learning orchestrations could be a result of students trying to adapt their approach to the learning environment. Further work should be carried out to establish if these disintegrated perceptions/approaches are stable or if it is evidence of an approach in transition.

The crux of the approach is to be seen to be participating, so students will focus on doing work in-between class in the form of learning issues and then using this work to participate in the next session. They describe their approach as asking questions as they feel this is a way to portray that they are seeking the understanding that the tutors expect of them and, from the observation results, it is apparent that these students ask a lot of questions but, as with the other approaches, these questions are limited by their conception of understanding so they are not looking to fully understand the concepts but to get a repeatable understanding of the concepts. As they have the intention of solving the problem, they also describe looking for equations to solve the problem through variable recognition. Again, the observation results show that the students do this in the problem-based learning sessions and it is often the emphasis of their work in-between classes.

Overall, students just want to be seen to be participating and they believe that they are participating in a way in which the tutors have told them to. This is indicated in that they were often told that asking questions is a good way of contributing and so they do so. But as indicated previously in this discussion, it is the quality of the questions they ask that lets them down. They indicate that a lot of factors will affect how they participate, such as prior knowledge, learning issues and the group members they are with. As indicated, these students are not unmotivated like some of the strategic students and prepare for exams and do work in-between classes. Several ways that the *PBL surface* approach manifests itself in the way in which students participate have been indicated already but most importantly, in regard to the observation results, is the lack of observable participation that involved the development of understanding. These students do not discuss, explain or disagree with their understanding with much frequency and, hence, do not assist in the development of their own understanding. However, it would appear that these students think that they are developing understanding because by their perception they are doing what they have been told to do and so think that they should be developing an understanding. The problem is that they do not understand what understanding is.

With regard to their scores on assessments and conceptual evaluations, the *PBL surface* students scored lowest on all examinations and on the FMCE, with significant lower results than those of the two other approaches. In fact, the problem-based learning continuous assessment is the only assessment in which they received equal marks to students adopting the other approaches. However, as discussed previously, this is probably more related to the nature of the assessment method than the students being at the same level when working in groups. From the background information, an interesting point is that half of these students have no prior physics experience. This could be a contributing factor to their approach and conception of understanding as they have no experience of the interconnected relationship between physics concepts. On the CLASS, the students with the *PBL sufface* approach had a similar agreement with the experts on the overall category but again interestingly, they had the lowest scores on the two conceptual categories indicating again the lack of equality between their conception of what it means to understand a concept in physics and that of an expert. The problem that students with this approach have is they do not understand what understanding is in physics.

10.5 Chapter Summary

In summary, the approaches to learning seem to be highly dependent on students conception of understanding in a physics problem-based learning course. Their resulting actions also seem dependent on this conception of understanding in that their level of participation through understanding is limited. This chapter also indicated that each of the three approaches found resulted in a different level of achievement in regard to development of conceptual understanding and in relation to achievement in assessments except for in problem-based learning process mark which may be indicative of inadequacies in that form of assessment. Three distinct categories where found with four distinct perceptions of the learning environment. Parallels were drawn between traditional deep, strategic and surface approaches and *PBL deep*, *PBL strategic* and *PBL surface* approaches respectively. Distinctions between these traditional approaches and the problem-based learning approaches were also indicated which appear to be as a result of the learning environment. The next chapter concludes the findings from this research study and discuss recommendations and future research which might spawn from these conclusions.

CHAPTER 11

CONCLUSIONS AND IMPLICATIONS AND FURTHER WORK

11.1 Introduction

This main aim of this research study was to investigate the variations in introductory physics students' approach to their learning in a problem-based learning environment that is constructively aligned to develop understanding. As part of this investigation of variation of approaches, students conceptions of understanding were also investigated in addition to the students' perceptions of the problem-based learning environment. Using the phenomenographic assumptions and methodology the variations in the participating students' approaches to their learning, conceptions of understanding and perception of learning environment were discovered. The study observed the actions of students during problem-based learning sessions in order to establish if categories of approach manifested in specific ways. It also examined the students' normalised gains on the FMCE and their results on continuous assessments and end of year assessments. Furthermore, it explored several different relationships including: the relationship between approaches and perceptions of learning environment; the relationship between approach/perception and manifestation of actions; the relationship between approach/perception/actions and results on learning outcomes/conceptual evaluations. The main findings and implications from this study are summarised below, followed by the final concluding remarks.

11.2 Summary of findings

The most significant finding to come from this research was the descriptions of the approaches to learning within the problem-based learning environment. The effectiveness of problem-based learning as a method of delivery and the effectiveness of problem-based learning to influence students to adopt a deep approach to their learning cannot be discussed or critiqued without first taking into account the specific problem-based learning context. This research project has demonstrated that in a constructively aligned learning environment with a focus on conceptual understanding, students will adopt an approach to their learning that even in the worst case has deep elements. This research study defined new approaches to learning for the context of problem-based learning and these approaches demonstrate different levels of deep approaches. *PBL surface* and *PBL strategic* contain elements of their traditional counterparts but could be viewed as a level of deep approach due to the intentions of *PBL surface* and strategy of *PBL strategic*.

Another significant finding of this research study in regard to the approaches to learning is the link between a student's approach to learning and their conception of understanding. Students with a more sophisticated conception of what it means to understand a concept in physics will be more likely to have a *PBL deep* approach to their learning. Students who have a conception of understanding that is based around the usage of concepts will likely have a *PBL strategic* approach and students with the least sophisticated conception of understanding or ability to repeat or explain will likely have a *PBL surface* approach. The link between conception of understanding and approach is more specifically a link of enablement. Unlike previous approaches to learning research of surface approaches students in the *PBL surface* approach have an intention to understand. This again is an important finding and as indicated in the last paragraph this level of deepness to an otherwise surface approach demonstrates one of the effects the problem-based learning context has on students approaches to their learning. But it is their unsophisticated conception of understanding that results in these students not having the ability to adopt this pure deep approach their intention requires. This implies that in order to require students to adopt a *PBL deep* approach to their learning one must enhance the sophistication of what it means to understand a concept. So there is a direct link between conception of understanding and approach to learning as previous researchers have theorised and it is the key influence on how a student approaches their learning in the context of this studies problem-based learning environment. However this finding may be contextual and due to the constructive alignment and emphasis that the course and tutors place on understanding. This could be perceived as a limitation of the transferability of the results but on reflection any discussion of a problem-based learning course must assume it is constructively aligned otherwise the use of problem-based learning as a method of delivery would be redundant. The emphasis on understanding element of context would fall into the same argument. Should most higher education courses not be placing an emphasis on conceptual understanding. As can be seen from Ellis *et al.* 2007 study there is no mention of conception of understanding due to their being no emphasis on it within the learning outcomes due to the develop of practitioner goal of the course.

The findings revealed that students approach their learning in a physics problem-based learning course in one of three ways which are relatable to previous approaches to learning research: *PBL deep*, *PBL strategic* and *PBL surface*. Although each of the approaches bear a likeness to the previous well known deep, strategic and surface approaches to learning there are however clear differences between the problem-based learning approaches and traditional approaches. As discussed above one of the main differences between traditional and the problem-based learning approaches found in this study is conception of understanding. For the *PBL deep* approach though there is another significant difference and that is the absence of an intrinsic interest. Previous research in approaches to learning has indicated that a deep approach to learning is adopted by students who have an intrinsic interest in the subject. They want to understand and be fully immersed in the subject because of their love and affinity for it and do not care about grades. The *PBL deep* approach does not contain this intrinsic approach as the students adopting it do care about achievement. However the students did describe that a problem was not finished until every element of it was understood which was sometimes not a necessity to solve the problem. So they do have an intrinsic interest in the subject but they also care about how they are doing achievement wise in the course. This is agreement with previous research that has found students taking deep strategies to their learning without having the intrinsic interest. The major difference between the *PBL strategic* approach and the traditional strategic approach was the emphasis of their intention on solving the problem instead of trying to simply do well on assessment. The *PBL surface* approach differed from the original surface approach in intention; in the past the traditional surface approach has been indicative of students trying to get by with a least means possible attitude but students adopting the *PBL surface* approach have the intention to contribute and to understand.

Another major finding from this research study was the link between approach to learning and perception of the learning environment. As indicated in the literature review this link has long been established and this study found a similar connection. Findings from this study revealed that there are a limited number of qualitatively different ways in which students perceived the problem-based learning environment. Four perceptions of the learning environment were discovered and found to be directly linked to the three approaches to learning discovered. Uniquely two different perceptions result in the same approach which is not a common discovery in approaches to learning research. The four perceptions of the learning environment were "constructively aligned", "problem-solving", "participating" and "inappropriate" with "constructively aligned" linking to *PBL deep*, "participating" linked to *PBL surface* and "problem-solving" and "inappropriate" linking to *PBL strategic*. The perceptions of the learning environment would seem to indicate levels of awareness of the reasoning behind using a problem-based learning environment and it is this awareness combined with the conception of understanding that influences a student's approach to learning. As indicated in the discussion though both the perceptions of the learning environment and the approaches to learning may be just indicative of students approach for a particular time period with evidence that both the *PBL surface* and *PBL strategic* approaches may be approaches that are in the process of transition as a result of the change in learning environment on the part of student.

The findings from the observation of students working in groups indicate a correlation between students' approach/perception and their actions in the learning environment. With the *PBL deep* students spending the majority of the time focused on understanding. This was displayed in their actions by focusing on understanding rather than answering the question with discussion through explanation of their understanding or questioning others understanding the main focus of their actions. Another important finding from the observation research is that the *PBL strategic* students do not have the intention or aim to understand the physics unless required to do so to solve the problem. The design of the learning environment would seem to counter act this intention and force these students to participate in ways that focus on developing their understanding. The results also showed that *PBL surface* students spend the majority of time contributing trivially even though they have the intention to contribute and the belief that they are contributing the way that they should and they believe they are developing understanding. Their methods of participation are restricted by their limited conception of understanding.

The final findings of a quantitative nature suggest that there is an alignment between approach to learning and the levels of achievement on the FMCE conceptual evaluation and end of semester of exams of the students. With the *PBL deep* students achieving significantly higher gains on the FMCE and gains which are notably high in comparison to other research using the FMCE. There is a hierarchy of achievement on the FMCE and end of semester exams with the *PBL deep* at the top of the hierarchy and *PBL surface* at the bottom. These quantitative elements though are not statistically significant due to the nature of the study and are merely indicative and suggest further work which will be discussed in section 11.5.

11.3 Implications and recommendations

11.3.1 Implications for 'approaches to learning' research community

There are numerous implications for the approaches to learning community from this research study. The first is the important link that this research study established between a student's approach to learning and their conception of understanding in a problem-based learning environment which is constructively aligned to develop understanding. This link often referred to in previous research but never clearly proven has been established for this learning environment. This may encourage researchers in similar concept heavy environments to investigate if a link is present between students approach and conception of understanding. Another implication for the research community is to add to the argument against using inventories that have not been specifically developed or redeveloped with qualitative research for specific learning environments. The approaches to learning categories found in this study show significant differences than those that are attributed to the ASI and SPQ and if they had been used in this learning environment the instruments would not have given an accurate portrayal of the breakdown of students approaches in this learning environment. Another implication for the approaches to learning community is the direct link between students perception of the learning environment and their approach to learning which has been indicated before and this study adds further evidence. Importantly though, perception as indicated, is not the main influence on their approach to learning in this learning environment, instead conception of understanding and perception of learning combine to influence the students approach. These implications are a significant contribution to approaches to learning research and will be discussed again in relation to further work in section 11.5.

11.3.2 Implications for curriculum design

From one of the major findings from this study, that approaches to learning are linked to a conception of understanding in a problem-based learning environment that is constructively aligned to develop understanding, come significant implications for curriculum design. The findings from this study argue that in order to help students develop meta-cognitively they must be informed on learning itself and be prepared for the problem-based learning environment. Preparation of students could be approached on a number of different fronts. Consideration could be given to how students perceive the curriculum structure. For example, in an integrated curriculum where subjects are taught using a variety of teaching methods, explanation of the value of the different methods of teaching and learning need to be highlighted. This could be achieved by dedicating a subject early in the course in which students explore different approaches to learning or by using a “learning to learn” programme. Specifically, students could spend time in the problem-based learning groups initially discussing their understandings of the learning process which would serve to emphasise their differing conceptions of learning and understanding. Students could then be given the opportunity to explore and share how they might adapt their learning approach in line with different delivery styles they may encounter. In order for the students with the less sophisticated conceptions of understanding and therefore those taking a surface approach to evolve they must reflect and become aware of how they approach their learning.

Another aspect of the results that reflect on curriculum design is the verification by observation that students who even have negative feelings and approach the problem-based learning environment strategically will still contribute positively in problem-based learning sessions and develop conceptually. This signifies that if the right balance between tutor intervention and the problems in problem-based learning is struck then students adopting a strategic approach will be forced into choosing the deep approach over the surface approach. Further work investigating these aspects of the problem-based learning environment should be investigated to discover the exact nature of the effect both tutor intervention and the problems has on these students.

This research also highlights the positive effect that constructive aligning a course has on students learning outcomes. However in regards to constructive alignment, it has more of an effect, if the students have the awareness to interpret that the course is constructively aligned. The *PBL deep* students demonstrate an awareness of constructive alignment without knowing that is what they are perceiving. They align their perceptions of assessment and tutor outcomes with their own personal goals which is essence the ideal scenario when it comes to curriculum design. It is this awareness that contributes to students both taking a deep approach and achieving highly on assessments. This indicates the value of constructive alignment while also reinforcing the previous point that students have to be informed and encouraged to reflect on their own learning and perceptions of the learning environment.

Another implication for curriculum design is that if students are doing particularly poorly on an element of a course for example a particular mechanics concept, this could imply that the problem is not successful at encouraging strategic students to adopt a deep approach. In other words the problem could be encouraging the surface approach that the strategic students would prefer to use. Of course a conclusion from an element of a course that scores badly on a conceptual evaluation is that the problem that pertains to that concept needs to be reflected on. This highlights that the problems need to be designed so that a student taking a surface approach will not be rewarded for doing so.

11.3.3 Implications for tutors

There are several obvious implications of this research for tutors with the obvious being the categories of description of both variation in approach and perception will help tutors to identify students that are adopting the various approaches to the learning environment and intervene. If the tutors are aware of the students' approaches to learning they can encourage reflection on their approach and the conceptual nature of physics in order to push them towards a deeper approach to learning. For students identified to be surface it can be an indication that these students do not have a sophisticated conception of understanding and that it is not just their strategy to solving the problem that needs to be altered but their conception of understanding itself that needs to be reflected on and developed.

The results from the observation could be used to identify students that are not taking a deep approach to their learning and also identify some of the actions that could be conducive to having a deep approach. Again I am in no way positing that taking certain actions will result in a deep approach but it could be helpful in regards to encouraging strategic students into more of the students from the deep approaches actions. This is especially true in regards the feedback the students are given after problems, the list of actions will help tutors identify what ways students are not contributing and encourage them to contribute in different ways. For problem-based learning tutors the results for approach/perception/actions/learning outcomes would seem to suggest that students perform at relatively higher levels in problem-based learning situations but that, for these relatively higher levels to be met, they must ensure the strategic and surface students avoid surface strategies. The results would also seem to be indicative that tutors should encourage debate among the students as students will often communicate their understanding under such circumstances. Debate about understanding and students conceptions of understanding, learning and problem-based learning should also be encouraged among the students as it may help those with less sophisticated conceptions to transition to deeper sophistications of conceptions. The *PBL strategic* category would also seem to indicate that tutors should deemphasise the importance of getting a solution and try and get students to see past the satisfaction of getting a solution and look towards the greater satisfaction of developing an understanding. In essence the observation results are a guide to tutoring in a problem-based learning environment that is constructively aligned to develop understanding.

11.3.4 Implications for students

The implications for students are much the same as the implications for instructors in that the approaches to learning categories and perceptions of the learning environment categories will enable students to be specifically aware of the differences in approaches that one can approach the problem-based learning environment. For students these categories could highlight the need to reflect on their conception of learning and develop it while also making them do the same for their approach. Awareness of the variations of approaches should also highlight the limitations of their approach and encourage students to change to a deeper approach to their learning. The fundamental nature of changing ones approach is reflection and increased awareness and these approaches to learning categories should help students reflect and become more aware of what an approach to learning is in a problem-based learning course and hence develop meta-cognitively.

11.3.5 Implications for DIT School of Physics

A positive outcome of this research in regards to the DIT School of Physics is that the Level 8 problem-based learning course has both been proven to be constructively aligned and to encourage students to take a deep approach to their learning. Even if all the students are not taking a *PBL deep* approach the other two approaches have elements of a traditional deep approach. The *PBL surface* in its intention and *PBL strategic* in that they will adopt a deep approach is forced by the tutors or problems. This is justification for adoption of problem-based learning as an improved alternative to traditional method of teaching.

The implications for instructors are of course applicable to the DIT School of Physics problem-based learning tutors. So the tutors are now more aware of the approaches the students are taking to the learning environment and why they are taking those approaches.
It also highlights that one of problem-based learning continuous assessment mark needs to be reflected on more as it is not distinguishing between students who are contributing better than others. Although the main aim of this assessment is more motivational and reflective the fact that it does not distinguish between levels of contribution could be counterproductive motivationally.

The study also highlights that the students in the DIT problem-based learning course need more guidance on what it means to understand a concept in physics. This indicates the need for some sort of “learning to learn” module or the tutors to encourage more reflection and awareness when it comes to approach and conception of understanding to be integrated into the problem-based learning course.

11.4 Limitations of the study

As with all research studies there were limitations in this physics education research, although I tried to be aware of these limitations in an effort to minimise their effect on outcomes of the research

As was discussed previously at several junctures the quantitative elements of this study are merely indicative and are suggestive of further work. It is the nature of this type of research the student numbers will be relatively low and so the quantitative elements are not statistically significant. The next step would be to develop an inventory based on the qualitative results for approaches to learning and perception of learning environment that could be administered to students in conjunction with the FMCE in order to analyse all students who enter the problem-based learning course.

Another limitation which I was aware of while conducting this research was that the research study may have been designed differently and therefore the research findings may also have been different. If an alternative methodology was chosen, such as phenomenology, with which to conduct the research the outcomes may not have been the same. However the methodology employed in this study was deeply grounded in my theoretical assumptions that were brought to the research and which are fully justified and explained in Chapter 3. Included in the area of research design is the limitation of having a finite number of research participants. The methodology is also consistent with the learning theory and many of the studies previously carried out on learning approaches and perceptions of the learning environment.

Yet another limitation is the time period of which the study took place. As discussed previously the interviews were conducted after the conclusion of the mechanics section which is after the first semester which is 3 months after the students entered into the learning environment and so the approaches to learning found may be just indicative of approaches in transition as opposed to approaches that would be taken after a full year of study through problem-based learning. Another limitation comes from the context of the research setting; the research was carried out in one institution in one country. However readers can draw parallels to their own learning and teaching situation for the limitations which are mentioned in the above paragraphs.

11.5 Further Work

In many ways this research study has probably raised as many questions as it has answered and it was difficult to prevent the research from losing focus, as many interesting issues arose during the course of the study which could not be fully addressed due to lack of time. These issues have important implications for physics education and would benefit from further research, such as:

- Investigating the effect difference in profiles (e.g. educational background and pre FMCE results) has on students FMCE gain

- Develop an inventory based on the approaches to learning and perceptions of learning environment found in this study for use in any problem-based learning course constructively aligned that prioritises understanding.
- Undertake a longitudinal study with elements of the study again after self assessment has been used to see if the students become more reflective and hence more aware of their approach, hence, repeat elements of the study at a later period than this study to see if the approaches to learning found in this study are concrete or are merely a snap shot of approaches in transition.
- Similarly to the point above but focusing on actions this time, record the students working at two different time periods, when they begin problem-based learning and near the end of first year to see if actions change with more exposure to the learning environment.
- It is a recommendation of this research that students develop meta-cognitively and therefore further work would involve an examination of strategies to encourage this development.

11.6 Concluding Remarks

The objective of this thesis was to provide and overall description of students approaches to their learning and perception of their learning environment in a problem-based learning course that is constructively aligned to develop understanding by employing phenomenographic assumptions and methodology discussed in Chapter 3. This description has been achieved by constituting categories which describe the variations in approaches to learning and variations in perception of environment, including a description of the variations in conceptions of understanding for the problem-based learning environment.

One of the most important outcomes of this study is the relationship in this environment between conceptions of understanding and approach to learning. The study also outlined the link between approach and perception of the learning environment and indicated how the approaches found manifest in the students' actions in the learning environment.

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APPENDIX A:

TABLE OF LEAVING CERTIFICATE GRADES

Table A: Table of Leaving Certificate grades and corresponding CAO points awarded

Percentage Range	Grade	Points for Higher	Points for Ordinary
90 – 100	A1	100	60
85 – 89.9	A2	90	50
80 – 84.9	B1	85	45
75 – 79.9	B2	80	40
70 – 74.9	B3	75	35
65 – 69.9	C1	70	30
60 – 64.9	C2	65	25
55 – 59.9	C3	60	20
50 – 54.9	D1	55	15
45 – 49.9	D2	50	10
40 – 44.9	D3	45	5
25 – 39.9	E	0	0
10 – 24.9	F	0	0
0 – 9.9	NG	0	0

APPENDIX B:

SAMPLE PROBLEM BASED LEARNING PROBLEM

California Train Crash

To open this problem as a word document, click here.

Your group have been asked to take over an emergency situation at the California Train Control Centre. As none of the staff there have any special training, there wi be a terrible accident with high casualties unless you can find a solution to their problem. On entering the Centre you are informed of the following:

> There is a passenger train on the track which has a serious engine fault. The train has eight carriages with 200 passengers. The driver cannot control the speed so it is travelling at a constant velocity of 30 ms^{-1} in a north-east direction. This train has only 9 km of track left. You can communicate with the driver but he has no control over the engine.
>
> However there is another engine (engine only) on the same track 600 metres behind the uncontrolled train. You can communicate with this driver and he has complete control over the engine. You can assume that the 600 metres is the distance from the front of one train to the back of the other. The track between the trains is straight as is the remaining 9 km.
>
> At the moment the two trains are travelling at the same speed.
>
> An engineer in the Centre informs you that if the train behind were to catch up to train ahead the trains can be remotely connected together. The leading engine can then be switched off. Then the train behind can be used to stop the other train. However the connection has to be made when both trains are travelling at the same speed.

Remember time is running out.

After the accident has been avoided your team must fill in the attached **Form 11A**.

California Train Control Centre

Click here **to open FORM 11A which must be completed.**

California Train Specifications

Amtrak 462

Mass

Carriage	=	5.8×10^3 kg
Engine	=	1.4×10^4 kg
Maximum Driving Force	=	6.3 kN
Maximum Braking Force	=	6.0 kN
Maximum Velocity	=	180 km/hr
Engine Maximum Load	=	8 Full Carriages
Carriage Capacity	=	80 people

Figure B1: First mechanics problem given to level 8 students

APPENDIX C:

CHIRIAC MODEL OF GROUP ANALYSIS

The following sections are taken from Chiriac 2007 and give further detail to the theoretical model explained in the paper.

An *additive* task requires that all members' contributions to the work are weighted equally and then added together. The added sum is the group's result (e.g. pulling a rope).

The *disjunctive* task depends only on the most successful member to find and present the solution to the problem (e.g. problem-solving). In a disjunctive task group members do not have to co-operate to accomplish the task.

The *conjunctive* task is dependent on the weakest member, i.e. all members in the group must complete the task (e.g. mountain climbing).

The group must balance the average from all group members' opinions when they work with a *compensatory* task. The average is the group's result (e.g. choose the best comrade in a class).

A *complementary* task also involves the entire group's performance. The group work depends on the distribution of work among group members and that each member takes responsibility for his/her part of the work. The result is the sum of all members' contribution (e.g. writing an anthology).

The purpose of a *work group* is to manage the task in a rational and effective way (Bion 1961). The leader serves the group's purpose, and feelings like responsibility and cooperation are predominant. The *work group* handles changes and conflicts in a rational way.

In the *dependent* condition the group's aim is to get security and protection from the leader. The leader is perceived as omnipotent and the members depend on him/her. Feelings such as helplessness and inability of critical thinking are predominant. The *dependence group* will act against changes and denies conflicts.

The *fight group* tries to subdue anxiety through fighting against a presumed shared enemy, and the leader is expected to identify the enemy and command the fight. Feelings like aggression, hostility and paranoiac imaginations occur frequently. The *fight group* is suspicious of new ideas and conflicts are solved through fight.

The *flight group* tries to suppress anxiety through flight and hides from an experienced threat. The leader is expected to have a strategy for relieving the threat. Daydreaming, suspicion and generalisation dominate the atmosphere of the group. The members forget, do not hear or laugh off suggestions for changes. Conflicts are rare, but if a conflict would occur, common strategies are flight or denial.

The *pairing group* tries to reproduce itself. Two members in the group, a pair, are usually more active than the other members. The main emotion expressed in the group is expectation and hopeful anticipation. The leader is not ‘‘born’’ yet but the group is waiting for its saviour. Members have ‘‘fantasies’’ about a better future, and conflicts are not allowed to surface. The leader must remain unborn or the group’s basic-assumption will disappear and the group has no longer any function.

APPENDIX D:

ASSESSMENT OUTLINE FOR PROBLEM-BASED LEARNING

PBL in class assessment criteria
Contribution

The role of the every group member is to contribute to the group process and be responsible for group maintenance. The level of contribution can be evaluated and assessed against the following aspects of an individuals role within a group:

- **Actions**

The chair of the group can delegate tasks to individual members during the group process. Alternatively a group member may volunteer for a specific task. It is then the group member's responsibility to complete this task to the best of their ability and report back to the group. The group can expect the task to be completed on time and in full.

- **Working towards Understanding**

It is each member's responsibility to strive towards a complete understanding of the physics involved in each problem. It is not sufficient to just sit back and listen in the hope of learning something later but you must be actively engaged in the process and trying to understand the physics. This can be accomplished by regularly asking other group members questions, stating what you understand to be correct, summarising the groups' position, looking for mistakes in the process, thinking and calculations, and ensuring you understand the other group members.

- **Working towards Group Understanding**

One of the aims of the process is that by the end of a problem the group has achieved the same level of understanding. Each group member can promote the group learning by continuously asking each other questions to ensure everyone understands.

- **Peer Tutoring**

In many cases some of the group members will have a greater prior knowledge of the subject matter. In this situation it is their responsibility to help the other students learn by explaining and teaching the physics involved. In this way the students can learn from each other and also by teaching the subject the students with prior knowledge can identify any holes in their understanding.

- **Assisting Group Focus**

It is each members responsibility to help keep the group focused on the problem and to maintain a good group working environment.

- **Big Picture**

It is important to the process for each member to remain focussed on the overall objective of the problem and not to get distracted by small and maybe irrelevant elements.

Assessment of Contribution
The level of contribution will be assessed by the extent to which he/she displays the above attributes. However it must be noted that a student it not expected to complete the entire list. The tutor will award each student a mark from 1 to 10 based on how well the student exhibits the appropriate attributes. Each student will also be required to award himself/herself a mark from 1 to 10 based on the same criteria and justify the mark. The average of the marks will be the final grade awarded to the student. In the event the marks differ greatly the tutor will discuss and negotiate the final grade with the student. At the end of each session the tutor and each student will complete forms AS1 and AS2 respectively.

PBL Assessment form:

Problem: Group:
Tutor:

Name	Date	Date
	• Actions • Working towards understanding • Peer tutoring • Assisting group focus • Big Picture	
	• Actions • Working towards understanding • Peer tutoring • Assisting group focus • Big Picture	
	• Actions • Working towards understanding • Peer tutoring • Assisting group focus • Big Picture	
	• Actions • Working towards understanding • Peer tutoring • Assisting group focus • Big Picture	

	• Actions • Working towards understanding • Peer tutoring • Assisting group focus • Big Picture	
	• Actions • Working towards understanding • Peer tutoring • Assisting group focus • Big Picture	
	• Actions • Working towards understanding • Peer tutoring • Assisting group focus • Big Picture	

APPENDIX E:

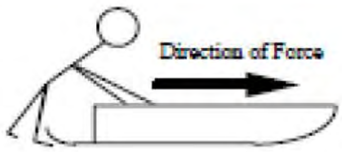
FORCE MOTION CONCEPTUAL EVALUATION

FORCE AND MOTION CONCEPTUAL EVALUATION

Directions: Answer questions 1-47 in spaces on the answer sheet. Be sure your name is on the answer sheet. Answer question 46a also on the answer sheet. Hand in the questions and the answer sheet.

A sled on ice moves in the ways described in questions 1-7 below. *Friction is so small that it can be ignored.* A person wearing spiked shoes standing on the ice can apply a force to the sled and push it along the ice. Choose the one force (**A** through **G**) which would **keep the sled moving** as described in each statement below.

You may use a choice more than once or not at all but choose only one answer for each blank. If you think that none is correct, answer choice **J**.

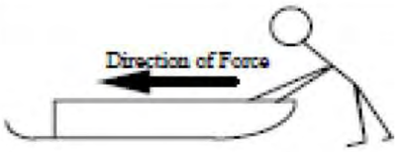


A. The force is toward the **right** and is **increasing** in strength (magnitude).

B. The force is toward the **right** and is of **constant** strength (magnitude).

C. The force is toward the **right** and is **decreasing** in strength (magnitude).

D. No applied force is needed



E. The force is toward the **left** and is **decreasing** in strength (magnitude).

F. The force is toward the **left** and is of **constant** strength (magnitude).

G. The force is toward the **left** and is **increasing** in strength (magnitude).

___1. Which force would keep the sled moving toward the right and speeding up at a steady rate (constant acceleration)?

___2. Which force would keep the sled moving toward the right at a steady (constant) velocity?

___3. The sled is moving toward the right. Which force would slow it down at a steady rate (constant acceleration)?

___4. Which force would keep the sled moving toward the left and speeding up at a steady rate (constant acceleration)?

___5. The sled was started from rest and pushed until it reached a steady (constant) velocity toward the right. Which force would keep the sled moving at this velocity?

___6. The sled is slowing down at a steady rate and has an acceleration to the right. Which force would account for this motion?

___7. The sled is moving toward the left. Which force would slow it down at a steady rate (constant acceleration)?

Questions 8-10 refer to a toy car which is given a quick push so that it rolls up an inclined ramp. After it is released, it rolls up, reaches its highest point and rolls back down again. *Friction is so small it can be ignored.*

Use one of the following choices (**A** through **G**) to indicate the **net force** acting on the car for each of the cases described below. Answer choice **J** if you think that none is correct.

(A) Net constant force down ramp
(B) Net increasing force down ramp
(C) Net decreasing force down ramp
(D) Net force zero
(E) Net constant force up ramp
(F) Net increasing force up ramp
(G) Net decreasing force up ramp

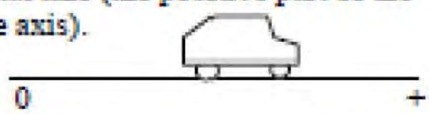
______8. The car is moving up the ramp after it is released.
______9. The car is at its highest point.
______10. The car is moving down the ramp.

Questions 11-13 refer to a coin which is tossed straight up into the air. After it is released it moves upward, reaches its highest point and falls back down again. Use one of the following choices (**A** through **G**) to indicate the force acting on the coin for each of the cases described below. Answer choice **J** if you think that none is correct. **Ignore any effects of air resistance.**

A. The force is **down** and constant.
B. The force is **down** and increasing
C. The force is **down** and decreasing
D. The force is zero.
E. The force is **up** and constant.
F. The force is **up** and increasing
G. The force is **up** and decreasing

______11. The coin is moving upward after it is released.
______12. The coin is at its highest point.
______13. The coin is moving downward.

Questions 14-21 refer to a toy car which can move to the right or left along a horizontal line (the positive part of the distance axis).



Assume that friction is so small that it can be ignored.

A force is applied to the car. Choose the one force graph (**A** through **H**) for each statement below which could allow the described motion of the car to continue.

You may use a choice more than once or not at all. If you think that none is correct, answer choice **J**.

__14. The car moves toward the right (away from the origin) with a steady (constant) velocity.

__15. The car is at rest.

__16. The car moves toward the right and is speeding up at a steady rate (constant acceleration).

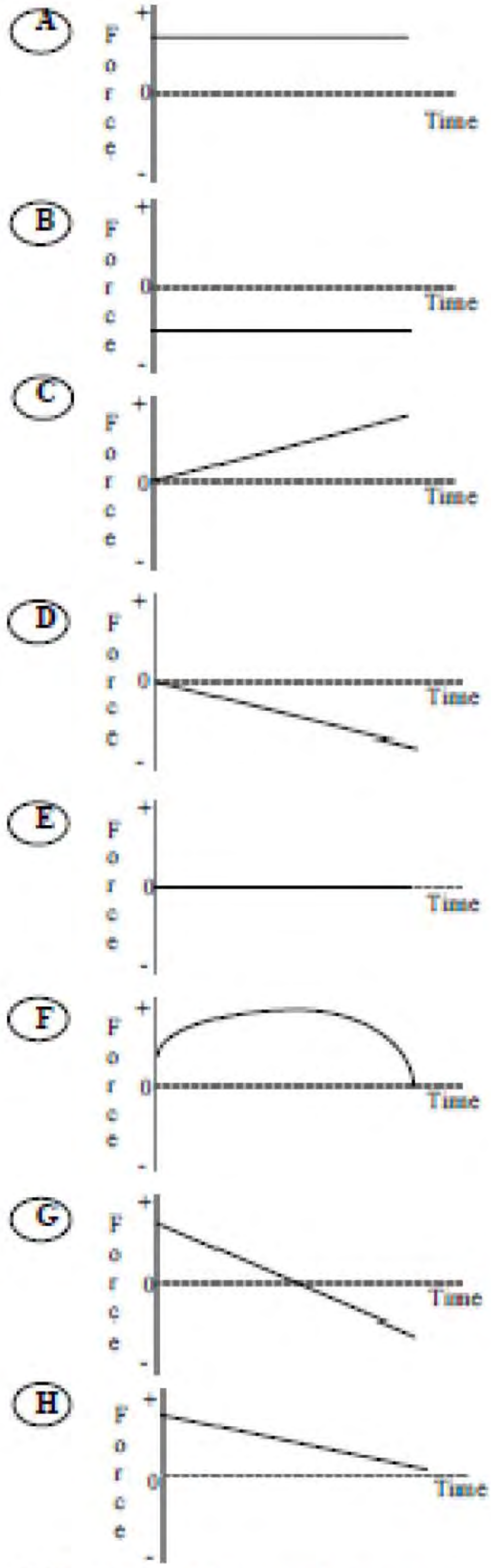
__17. The car moves toward the left (toward the origin) with a steady (constant) velocity.

__18. The car moves toward the right and is slowing down at a steady rate (constant acceleration).

__19. The car moves toward the left and is speeding up at a steady rate (constant acceleration).

__20. The car moves toward the right, speeds up and then slows down.

__21. The car was pushed toward the right and then released. Which graph describes the force after the car is released.

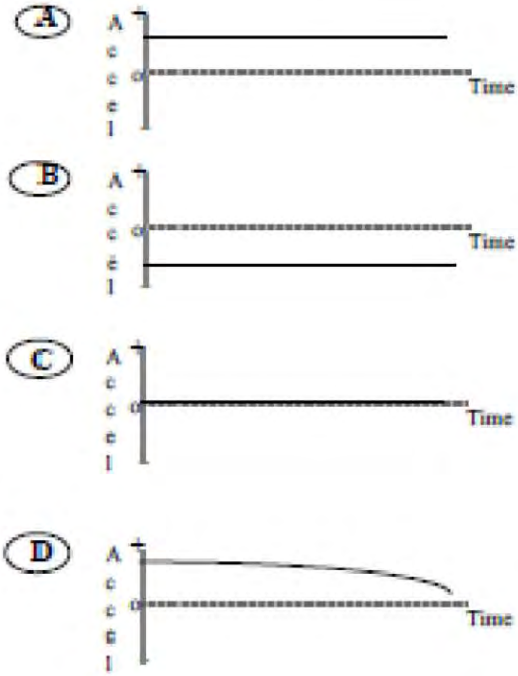


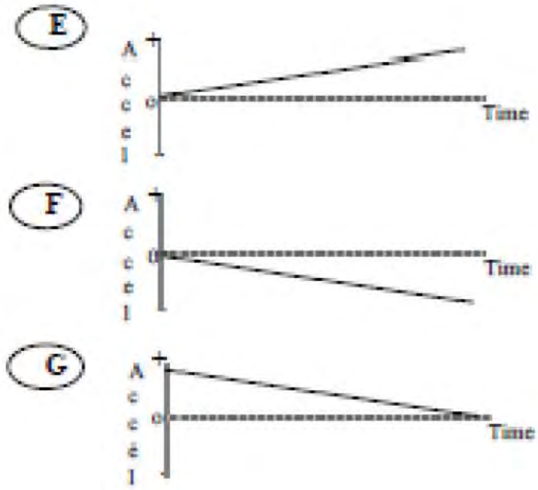
(J) None of these graphs is correct.

Questions 22-26 refer to a toy car which can move to the right or left on a horizontal surface along a straight line (the + distance axis). The positive direction is to the right.

Different motions of the car are described below. Choose the letter (**A** to **G**) of the **acceleration-time** graph which corresponds to the motion of the car described in each statement.

You may use a choice more than once or not at all. If you think that none is correct, answer choice **J**.





(J) None of these graphs is correct.

_____22. The car moves toward the right (away from the origin), speeding up at a steady rate.

_____23. The car moves toward the right, slowing down at a steady rate.

_____24. The car moves toward the left (toward the origin) at a constant velocity.

_____25. The car moves toward the left, speeding up at a steady rate.

_____26. The car moves toward the right at a constant velocity.

Questions 27-29 refer to a coin that is tossed straight up into the air. After it is released it moves upward, reaches its highest point and falls back down again. Use one of the following choices (A through G) to indicate the acceleration of the coin during each of the stages of the coin's motion described below. Take **up** to be the **positive** direction. Answer choice J if you think that none is correct.

- **A.** The acceleration is in the negative direction and constant.
- **B.** The acceleration is in the negative direction and increasing
- **C.** The acceleration is in the negative direction and decreasing
- **D.** The acceleration is zero.
- **E.** The acceleration is in the positive direction and constant
- **F.** The acceleration is in the positive direction and increasing
- **G.** The acceleration is in the positive direction and decreasing

__27. The coin is moving upward after it is released.

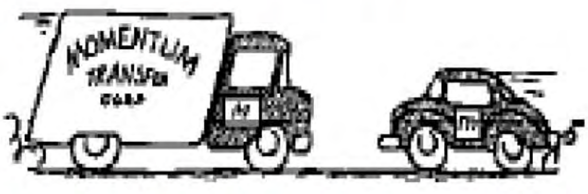
__28. The coin is at its highest point.

__29. The coin is moving downward.

Questions 30-34 refer to collisions between a car and trucks. For each description of a collision (30-34) below, choose the one answer from the possibilities **A** though **J** that best describes the forces between the car and the truck.

- **A.** The truck exerts a greater amount of force on the car than the car exerts on the truck.
- **B.** The car exerts a greater amount of force on the truck than the truck exerts on the car.
- **C.** Neither exerts a force on the other; the car gets smashed simply because it is in the way of the truck.
- **D.** The truck exerts a force on the car but the car doesn't exert a force on the truck.
- **E.** The truck exerts the same amount of force on the car as the car exerts on the truck.
- **F.** Not enough information is given to pick one of the answers above.
- **J.** None of the answers above describes the situation correctly.

In questions 30 through 32 the truck is ***much heavier*** *than the car .*



____30. They are both moving at the same speed when they collide. Which choice describes the forces?

____31. The car is moving much faster than the heavier truck when they collide. Which choice describes the forces?

____32. The heavier truck is standing still when the car hits it. Which choice describes the forces?

In questions 33 and 34 the truck is a small pickup and is the same weight as the car.

_____33. Both the truck and the car are moving at the same speed when they collide. Which choice describes the forces?

_____34. The truck is standing still when the car hits it. Which choice describes the forces?

Questions 35-38 refer to a large truck which breaks down out on the road and receives a push back to town by a small compact car.

Pick one of the choices **A** through **J** below which correctly describes the forces between the car and the truck for each of the descriptions (35-38).

A. The force of the car pushing against the truck is equal to that of the truck pushing back against the car.

B. The force of the car pushing against the truck is less than that of the truck pushing back against the car.

C. The force of the car pushing against the truck is greater than that of the truck pushing back against the car.

D. The car's engine is running so it applies a force as it pushes against the truck, but the truck's engine isn't running so it can't push back with a force against the car.

E. Neither the car nor the truck exert any force on each other. The truck is pushed forward simply because it is in the way of the car.

J. None of these descriptions is correct.

_____35. The car is pushing on the truck, but not hard enough to make the truck move.

_____36. The car, still pushing the truck, is **speeding up** to get to cruising speed.

_____37. The car, still pushing the truck, is at cruising speed and continues to travel at the **same speed**.

_____38. The car, still pushing the truck, is at cruising speed when the truck puts on its brakes and causes the car to **slow down**.

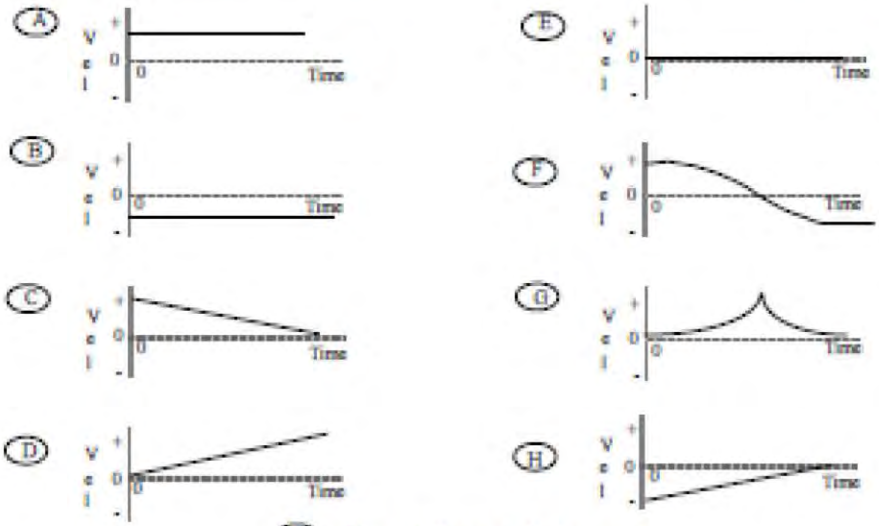
___39. Two students sit in identical office chairs facing each other. Bob has a mass of 95 kg, while Jim has a mass of 77 kg. Bob places his bare feet on Jim's knees, as shown to the right. Bob then suddenly pushes outward with his feet, causing both chairs to move. In this situation, while Bob's feet are in contact with Jim's knees,

Bob Jim

- **A.** Neither student exerts a force on the other.
- **B.** Bob exerts a force on Jim, but Jim doesn't exert any force on Bob.
- **C.** Each student exerts a force on the other, but Jim exerts the larger force.
- **D.** Each student exerts a force on the other, but Bob exerts the larger force.
- **E.** Each student exerts the same amount of force on the other.
- **J.** None of these answers is correct.

Questions 40-43 refer to a toy car which can move to the right or left along a horizontal line (the positive portion of the distance axis). The positive direction is to the right.

Choose the correct velocity-time graph (**A** - **G**) for each of the following questions. You may use a graph more than once or not at all. If you think that none is correct, answer choice **J**.



(J) None of these graphs is correct.

___40. Which velocity graph shows the car moving toward the right (away from the origin) at a steady (constant) velocity?

___41. Which velocity graph shows the car reversing direction?

___42. Which velocity graph shows the car moving toward the left (toward the origin) at a steady (constant) velocity?

___43. Which velocity graph shows the car increasing its *speed* at a steady (constant) rate?

A sled is pulled up to the top of a hill. The sketch above indicates the shape of the hill. At the top of the hill the sled is released from rest and allowed to coast down the hill. At the bottom of the hill the sled has a speed v and a kinetic energy E (the energy due to the sled's motion). Answer the following questions. ***In every case friction and air resistance are so small they can be ignored.***

__44. The sled is pulled up a **steeper** hill of the **same** height as the hill described above. How will the velocity of the sled at the bottom of the hill (after it has slid down) compare to that of the sled at the botom of the original hill? Choose the best answer below.

A. The speed at the bottom is greater for the steeper hill.
B. The speed at the bottom is the same for both hills.
C. The speed at the bottom is greater for the original hill because the sled travels further.
D. There is not enough information given to say which speed at the bottom is faster.
J. None of these descriptions is correct.

__45. Compare the kinetic energy (energy of motion) of the sled at the bottom for the original hill and the steeper hill in the previous problem. Choose the best answer below.

A. The kinetic energy of the sled at the bottom is greater for the steeper hill.
B. The kinetic energy of the sled at the bottom is the same for both hills.
C. The kinetic energy at the bottom is greater for the original hill.
D. There is not enough information given to say which kinetic energy is greater.
J. None of these descriptions is correct.

__46. The sled is pulled up a **higher** hill that is **less** steep than the original hill described before question 44. How does the speed of the sled at the bottom of the hill (after it has slid down) compare to that of the sled at the bottom of the original hill?

A. The speed at the bottom is greater for the higher but less steep hill than for the original.
B. The speed at the bottom is the same for both hills.
C. The speed at the bottom is greater for the original hill.
D. There is not enough information given to say which speed at the bottom is faster.
J. None of these descriptions is correct.

46a. Describe in words your reasoning in reaching your answer to question 46. (**Answer on the answer sheet** and use as much space as you need)

_47. For the higher hill that is less steep, how does the kinetic energy of the sled at the bottom of the hill after it has slid down compare to that of the original hill?

A. The kinetic energy of the sled at the bottom is greater for the higher but less steep hill.
B. The kinetic energy of the sled at the bottom is the same for both hills.
C. The kinetic energy at the bottom is greater for the original hill.
D. There is not enough information given to say which kinetic energy is greater.
J. None of these descriptions is correct.

APPENDIX F:

ETHICS STATEMENT AND LETTER OF CONSENT

As an education researcher, I realise that I am in a position of responsibility and trust, and this statement aims to show this.

“Whilst carrying out this research, I will observe the highest possible ethical standards. I will maintain integrity at all times regarding data gathering. I will only report information that is in the public domain and within the law. I will avoid plagiarism and fully acknowledge the work of others to which I have referred to in this study. I will report my findings honestly. I consider the research project worthwhile and of benefit to the academic staff and students with whom I work.

The permission of all the participants will be sought from each individual participant prior to any data collection. The identity of all undergraduate and postgraduate participants will remain anonymous in any and all disseminations of this research.

This research is designed to operate within an ethic of respect for any persons involved directly or indirectly in the research process, regardless of age, sex, race, religion, political beliefs, and lifestyle.

I recognise the importance of all participants in the research understanding the process in which they are to be engaged, including why their participation is necessary, how it will be used and how and to whom it will be reported.

I recognise the right of any participant to withdraw from the research for any or no reason, and at any time, and I will inform them of this right.

I intend to debrief participants at the conclusion of the research, to provide participants with copies of talk aloud protocol recordings and make available any reports or other publications arising from their participation."

Paul Irving

Physics Education Research Group

School of Physics

Dublin Institute of Technology

Kevin Street

Dublin 8

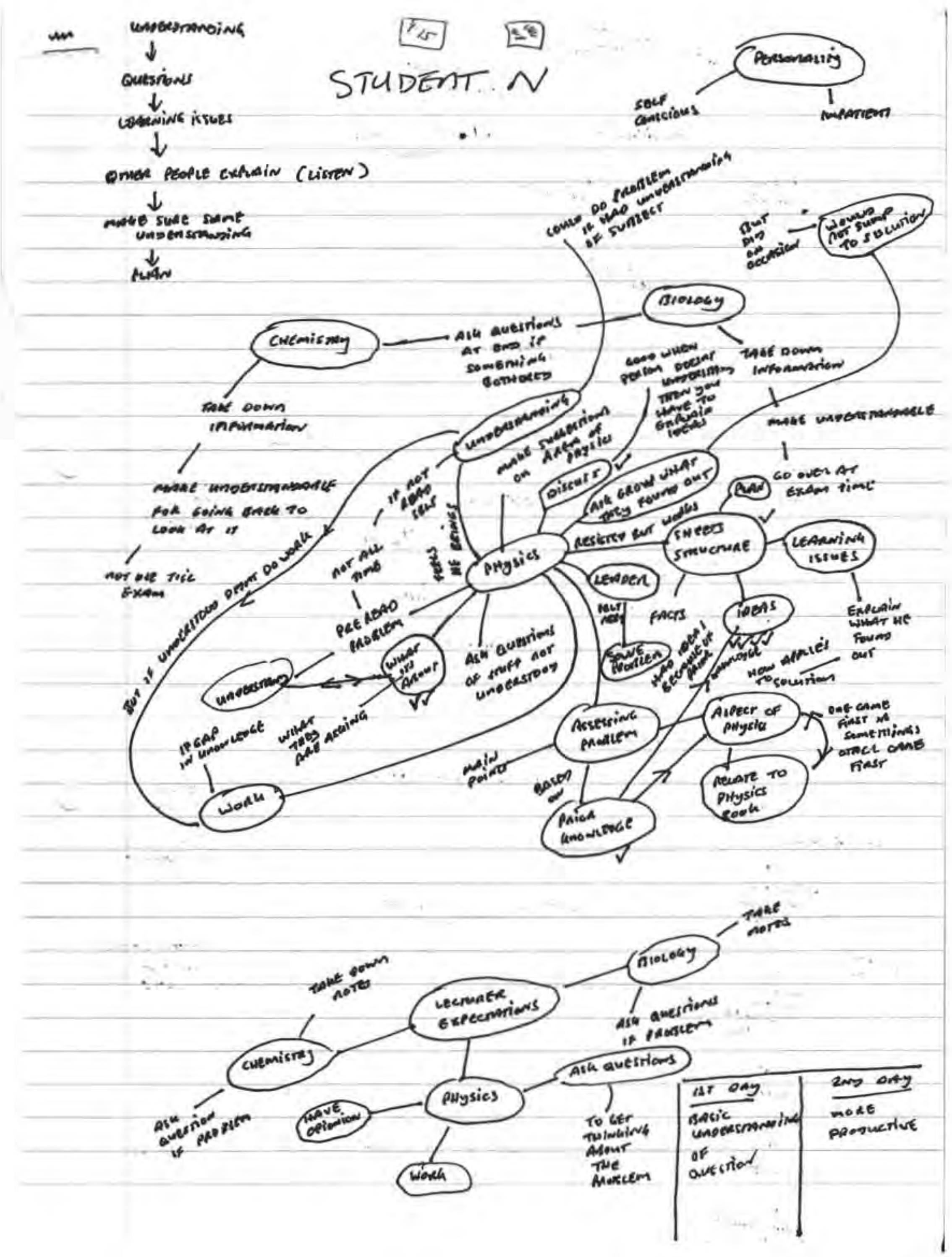
Ireland.

I, …………………….., have read the above ethics statement and agree to participate in the research outlined by Paul Irving

Signed……………… Date………………………

APPENDIX G:

SAMPLE SPIDER DIAGRAM FROM INTERVIEW ANALYSIS



APPENDIX H:

STUDENT ACTION DIAGRAMS

PBL Deep/Constructively Aligned

Student Name	Session 1 (Riverboat)	Session 2 (Riverboat)	Session 1 (Iditarod)	Session 2 (Iditarod)	Session 1 (Toxic Lift)	Session 2 (Toxic Lift)
Student N						
Actions	Puts forward ideas		Puts forward ideas		Puts forward ideas	Put forward ideas
	Explains understanding to group	Explains understanding to group	Explains understanding to group	Explains understanding to group	Explains understanding to group	Explains understand to group
	Plans		Plans			Plans
	Calculates	Calculates		Calculates		
	Answers tutor questions (directed/undirected)	Answers tutor questions (directed/undirected)	Answers tutor questions (directed/undirected)	Answers tutor questions (directed/undirected)	Answers tutor questions (directed/undirected)	Answers tutor questions (directed/undirected)
	Leads group (to get solution)		Leads group(to get understanding)	Leads group (to get understanding)		Leads group (to get understanding)
	Asks questions of group (understanding)	Asks questions of group (understanding)			Asks questions of group (understanding)	Asks questions of group (understanding)
	Makes clarifications					Makes clarifications
	Answers group questions					
	Leads solution at flip chart	Leads solution at flip chart	Leads solution at flip chart		Leads solution at flip chart	Leads solution at flip chart
	Discusses with whole group		Discusses with whole group			Discusses with whole group
	Discusses with individual group member				Discusses with individual group member	
		Completed learning issue		Completed learning issue		
		Relates learning issue to problem				
		Disagrees with group member (with explanation)		Disagrees with group member (with explanation)	Disagrees with group member (with explanation)	
		Delegates tasks		Delegates tasks	Delegates tasks	
		Asks questions for clarification			Asks questions for clarification	
			Reads problem to group			
			Identifies learning isssues		Identifies learning issues	
			Directs group member	Directs group members	Directs group members	Directs group members
				Corrects calculations		
					Records	
					Asks tutor questions	Asks tutor questions
					Arranges for group to meet up	
						Repeats explanations of understanding

PBL strategic/problem solving

Student Name	Session 1 (Riverboat)	Session 2 (Riverboat)	Session 1 (Iditarod)	Session 2 (Iditarod)	Session 1 (Toxic Lift)	Session 2 (Toxic Lift)
Student M						
Actions	Discussing (individual + group)	Discussing (individual + group)	Discussing (individual + group)	Discussing (individual + group)	Discussing (individual + group)	Discussing (individual + group)
	Directs group member			Directs group member	Directs group member	Directs group member
	Leads group		Leads group	Leads group		
	Answers tutor questions (non directed)					
	Plans		Plans		Plans	
	Discussing (tutor)				Discussing (tutor)	
	Puts forward ideas		Puts forward ideas	Puts forward ideas (solution)	Puts forward ideas	Puts forwards ideas (solution)
	Records	Records		Records	Records	Records
	Asks questions for agreement					
	Disagrees with group member					
		Completed learning issue		Completed learning issue		
		Expalins understanding		Explains understanding	Explains understanding	
		Discussing (building ideas)		Discussing (building ideas)		Discussing (building ideas)
		Calculates		Calculates	Calculates	Calculates
			Discussing - building ideas		Discussing - building ideas	
			Watching			
			Suggests meeting outside of class			
				Asks questions for clarification (understanding)		Ask questions for clarification (understanding)
						Sets up flip charts
						Checks calculations

Student Name	Session 1 (Riverboat)	Session 2 (Riverboat)	Session 1 (Iditarod)	Session 2 (Iditarod)	Session 1 (Toxic Lift)	Session 2 (Toxic Lift)
Student O						
Actions	Puts forward ideas	Puts forward ideas (solution)	Puts forward ideas	Puts forward ideas (solution)	Puts forward ideas	Puts forward ideas (solution)
	Ask questions about goal of problem		Ask questions about goal of problem			Asks questions about goal of problem
	Discusses with individual group member				Discusses with individual group member	
	Asks questions for clarification	Asks questions for clarification	Asks questions for clarification	Asks questions for clarification		Asks questions for clarification
	Explains understanding to group	Explains understanding to group		Explains understanding to group		
	Ignores Student T	Ignores Student T				
	Disagrees with group member (no explanation)	Disagrees with group member (no explanation)			Disagrees with group member (no explanation)	
	Answers tutor question (directed)			Answer tutor question (directed)	Answer tutor question (undirected)	
		Explains ideas to group (directed)				
	Recording	Recording	Recording	Recording	Recording	
		Discusses with group (building ideas)	Discusses with group (building ideas)	Discusses with group (building ideas)		
		Learning issues uncompleted				
		Calculates		Calculates		Calculates
		Answers tutor question (undirected)				
			Talks off topic	Talks off topic	Talks off topic	Talks off topic
			States misunderstanding and asks for explanation			
			Asks tutor questions			
				Asks questions for understanding		
				Quiet	Quiet	Quiet
				Watching		
				Directs group member		
					Agrees with group member	
						Disagrees with way student Q is treating student T

Student Name	Session 1 (Riverboat)	Session 2 (Riverboat)	Session 1 (Iditarod)	Session 2 (Iditarod)	Session 1 (Toxic Lift)	Session 2 (Toxic Lift)
Student P						
Actions	Watching		Watching			
	Quiet					Quiet
	Makes clarifications					
	Discusses (group)					
	Answers tutor questions (undirected)		Answers tutor questions (directed + undirected)	Answers tutor questions (undirected)	Answers tutor questions (directed + undirected)	Answers tutor questions (directed)
	Discussing (building ideas)				Discussing (building ideas)	Discussing (building ideas)
		Completed learning issue				
		Calculates		Calculates		Calculates
		Explains understanding to group	Explains understanding to group		Explains understanding to group	
		Explains understanding to tutor (directed)				
		Works by self				
			Plans			
	Put forward ideas		Put forward ideas		Put forward ideas	
			Directs group members	Directs group members	Directs group members	
		Records		Records	Records	Records
				Asks questions (solution directed)		

PBL surface/participative

Student Name	Session 1 (Riverboat)	Session 2 (Riverboat)	Session 1 (Iditarod)	Session 2 (Iditarod)	Session 1 (Toxic Lift)	Session 2 (Toxic Lift)
Student T						
Actions	Puts forward ideas				Puts forward ideas	
	Calculates	Calculates		Calculates	Calculates	
	Asks questions for clarification	Asks questions for clarification	Asks questions for clarification	Asks questions for clarification	Asks questions for clarification	Asks questions for clarification
	Watching	Watching		Watching		
	Quiet			Quiet		Quiet
	Ask tutor question (clarification)					
	Works by self	Works by self	Works by self		Works by self	Works by self
	Asks group for explanation	Asks group for explanation				Asks group for explanation
	States that they do not understand (no explanation)	States that they do not understand (no explanation)			States that they do not understand (no explanation)	States that they do not understand (no explanation)
	Asks questions about goal of problem	Asks questions about goal of problem				Asks questions about goal of problem
	Asks questions of no substance	Asks questions of no substance		Asks questions of no substance	Asks questions of no substance	Asks questions of no substance
		Completed learning issue		Completed learning issue		Completed learning issue
		Recording				
		Disagrees with group member (no explanation)			Disagress with group member (with explanation)	Disagrees with group member (with explanation)
		Explains understanding partially (directed)				
			Asks for explanation (tutor present)			
			Talks off topic		Talks off topic	Talks off topic
			Suggests structure			
			Suggests finding the formula		Suggests finding the formula	
			Ignores tutor			
				Learning issue not completed		
				Says understands without explaining it		
				Asks questions for direction		

Student Name	Session 1 (Riverboat)	Session 2 (Riverboat)	Session 1 (Iditarod)	Session 2 (Iditarod)	Session 1 (Toxic Lift)	Session 2 (Toxic Lift)
Student S						
Actions	Watching	Watching	Watching	Watching	Watching	
	Recording - Directed		Recording - Directed		Recording - Directed	
	Discussing - Minimal		Discussing - Minimal			Discussing -Minimal
	Takes notes					
	Quiet	Quiet			Quiet	Quiet
		Answers tutor questions - directed		Answers tutor questions - directed		
		Completed learning issue		Completed learning issue		Completed learning issue
		Putting forward ideas (minimal)			Putting forward ideas (minimal)	
			Reading book		Reading book	
				Discussing - tutor		Discussing - tutor
		Calculates				Calculates
		Asks questions for clarification	Asks questions for clarification			Asks questions for clarification
				Suggests finding an equation		

Student K						
Actions	Puts forward ideas	Puts forward ideas			Puts forward ideas	
	Discusses with individual group member					
	Asks questions for clarification	Asks questions for clarification	Asks questions for clarification		Asks questions for clarification	Asks questions for clarification
	Calculates	Calculates		Calculates		Calculates
	Discusses with group (no substance)		Discuses with group (minimally)			
		Learning issue completed		Learning issue completed		Learning issue completed
		Answers tutor question (directed)		Answers tutor questions (directed)		Answers tutor questions (directed)
		Asks questions about goal of problem		Asks questions about goal of the problem	Asks questions about goal of problem	
			Recording	Recording (directed)	Recording (directed)	
			Asks questions for agreement	Asks questions for agreement		
			Answers questions (directed at them)			
			Sets up flip charts		Sets up flip charts	Sets up flip charts
				Suggests finding the formula		
				Quiet	Quiet	Quiet
						Plans
						Leads the group

Student Name	Session 1 (Riverboat)	Session 2 (Riverboat)	Session 1 (Iditarod)	Session 2 (Iditarod)	Session 1 (Toxic Lift)	Session 2 (Toxic Lift)
Student R						
Actions	Set-up flip charts	Set-up flip charts				Set-up flip charts
	Discussing - Building Ideas					
	Discussing		Discussing		Discussing	
	Recording	Recording	Recording	Recording	Recording	Recording
	Discussing - Tutor					Discussing - Tutor
	Watching		Watching	Watching	Watching	
		Ask questions of group (understanding)		Ask questions of group (understanding)	Ask questions of group (understanding)	Ask questions of group (understanding)
		Completed learning issue		Completed learning issue		Completed learning issue
		Corrects calculations				
		Discussing (group)	Discussing (group)	Discussing (group)	Discussing (group)	Discussing (group)
		Calculates				
		Ask tutor question (clarification)		Asks questions for clarification		Asks questions for clarification
		Explains solution		Explains solution		
		Discussing (individual)	Discussing (individual)	Discussing (individual)	Discussing (individual)	Discussing (individual)
			Reading book			
				Explaining understanding	Explaining understanding	Explaining understanding
				Putting forward ideas		Putting forward ideas
				Relates learning issue to problem		

PBL strategic/inappropriate

Student Name	Session 1 (Riverboat)	Session 2 (Riverboat)	Session 1 (Iditarod)	Session 2 (Iditarod)	Session 1 (Toxic Lift)	Session 2 (Toxic Lift)
Student Q						
Actions	Puts forward ideas		Puts forward ideas		Puts forward ideas	
	Discusses with whole group (when stuck)			Discusses with whole group (when stuck)		
	Ignores Student T (unless he deems he has somethign useful to contribute)	Ignores Student T (unless he deems he has soemthing useful to contribute)	Ignores Student T (unless he deems he has something useful to contribute)	Ignores Student T (unless he deems he has something useful to contribute)	Ignores Student T (unless he deems he has soemthing useful to contribute)	Ignores Student T (unless he deems he has something useful to contribute)
	Watching					
	Makes decision					
	Explains understanding to group	Explains understanding to group	Explains understanding to group		Explains understanding to group	Explains understanding to group
	Explains idea to group (directed)			Explains idea to group (directed)		
	Discusses with tutor			Discusses with tutor		
	Asks questions of group (understanding)			Asks questions of group (understanding)		Asks questions of group (understanding)
	Asks questions (solution directed)	Asks questions (solution directed)		Asks questions (solution directed)	Asks questions (solution directed)	
	Leads solution at flip chart					Leads solution at flip chart
		Talks off topic	Talks off topic		Talks off topic	Talks off topic
		Calculates		Calculates	Calculates	Calculates
		Disagrees with group member (with explanation)	Disagrees with group member (with explanation)	Disagrees with group member (with explanation)		
		Asks tutor questions				
		Quiet	Quiet			
		Did not do learning issue		Did not do learning issue		Did not do learning issue
			Recording			
			Leads group		Leads group	Leads group
			Suggests finding the formulas			
			States knowledge instead of explaining	States knowledge instead of explaining		
			Calculates	Calculates		
			Suggests learning issues			
				Refuses to explain understanding until tutor present		
				Directs group member		Directs group member
					Spends time distracting group	Spend time distracting group
					Disagrees without explanation	

Student Name	Session 1 (Riverboat)	Session 2 (Riverboat)	Session 1 (Iditarod)	Session 2 (Iditarod)	Session 1 (Toxic Lift)	Session 2 (Toxic Lift)
Student L						
Actions	Puts forward ideas	Puts forward ideas	Puts forward ideas		Puts forward ideas	
	Explains understanding to group	Explains understanding to group	Explains understanding to group	Explains understanding to group	Explains understanding to group	
	Calculates	Calculates		Calculates		Calculates
	Works byself	Works byself		Works byself		Works byself
	Explains understanding of concept more than once				Explains understanding of concept more than once	
	Makes clarifications		Makes clarifications		Makes clarifications	Makes clarifications
		Answers tutor questions (directed)			Answers tutor questions (undirected)	Answers tutor questions (undirected)
		Disagrees with group member (with explanation)		Disagrees with group member (with explanation)		
		Corrects calculations				
			Watching			
			Asks questions of group (understanding)			
			Discussing (group)			
				Explains understanding to tutor		Explains understanding to tutor (directed)
				Directs (group member)	Directs (group member)	
				Asks questions (solution directed)		Asks questions (solution directed)
				Disagrees and ignores tutor (no explanation)		
				Records	Records	
				Talks off topic	Talks off topic	
					Does not want to meet up inbetween classes	
						Ignores group member (Student N)