Addressing the learning of chemistry at undergraduate level:

- towards the development of independent learning

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Declaration

I hereby certify that this material, which I now submit for assessment on the programme of study leading to the award of Doctor of Philosophy, is entirely my own work, that I have exercised reasonable care to ensure that the work is original, and does not to the best of my knowledge breach any law of copyright, 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

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Abstract

A key focus of education is to encourage and provide opportunities for learning. Recent research in science education has identified challenges in teaching and learning of science such as declining student engagement, provision of appropriate assessment and transition between various stages of formal education. This study addresses these challenges. Firstly, the students' profiles was determined both as the student entered university and then as they progressed through their study. The profile includes an indication of the students' motivation, their preparedness for university, their expectations of university, their interaction with learning supports and their approaches to learning at university.

In this study, varied and changing student profiles have been observed. It has been shown that factors including student 'interest', 'learning responsibilities', 'student attendance' and their 'approaches to learning' are positively correlated with academic achievement. It has also been shown that these factors which correlate well with academic achievement are also those that become problem areas by the end of both first and second year i.e. changing student profiles show an increase in surface approach to learning, reduction in perceived preparedness to take on learning responsibilities and reduction in student engagement. It is clear that these contributing factors towards student learning are not mutually exclusive, in fact they are interconnected, e.g. the approach that students adopt towards their learning is a factor in the quality of their learning but the approach and thus the learning is also influenced by the learning environment.

With the knowledge of the student profile on entry to university, a first year undergraduate chemistry laboratory for general science students was developed and implemented with the focus of providing learning experiences that allowed for the development of a range of appropriate skills within the student as well as tackling issues of engagement and preparation for independent learning.

From detailed analysis of several aspects of the new laboratory course, a framework for undergraduate chemistry laboratories is proposed. Having addressed the purpose of laboratories, the framework addresses many of these aspects that are normally not present in first year laboratories, namely problem solving tasks, open -ended problems, experimental design and development of professional skills. Additionally, a student assessment system was introduced that rewarded students for several different elements of the laboratory including manipulative skills, data interpretation, knowledge of the task in hand, knowledge of the underlying concepts, as well as maintenance of a laboratory journal. Additional elements were introduced including verbal presentations, pre-laboratories and practical assessments.

This work clearly shows that implementation of such a framework has a positive effect on student learning and engagement and thereby is an appropriate learning environment. Additionally this work has shown that it is possible to implement such a system with large numbers of first year students by implementing, with adequate tutor training, a small group teaching environment for large heterogeneous groups of students.

Abbreviations

ASI – Approaches to studying inventory

ASSIST – Approaches and study skills inventory for students

DBT – digits backward test

DCU – Dublin City University

ETQL – Experience of teaching and learning inventory

FIT – Figure intersection test

ILP – Inventory of learning processes

ILS – Inventory of learning styles

LSQ – Learning and studying inventory

LTM – Long term memory

NC – No previous chemistry (Leaving Certificate)

PC – Previous chemistry (Leaving Certificate)

RASI – Revised approaches to studying inventory

RSC – Royal Society of Chemistry

SGT – Small group teaching

SPQ – Study process questionnaire

SPSS – Statistics package for social sciences

USR – undergraduate skills record

ZPD – Zone of proximal development

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"The important thing is not to stop questioning. Curiosity has its own reason for existing." – Albert Einstein

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Introduction

The overall aim of teaching is to increase / improve student learning within the knowledge domain and also in terms of skills and personal development. Teaching must also identify and emphasise factors which encourage students to engage in their own independent learning. In this study, some of these factors which influence student learning are investigated in the context of first year undergraduate chemistry. Factors that influence student learning are provided in Figure 1. These are listed under two headings - 'learner considerations' and 'teaching considerations'.

Figure 1: Factors influencing student learning

Learner Considerations:

Previous knowledge / learning experiences
Motivation
Interaction / engagement with learning supports
Expectations of learning / learning supports
Perceived preparedness
Approaches to learning

Teaching Considerations:

Overall aims
Learning environment
Assessment procedures

→ **"Student Learning"**

Challenges in teaching and learning of science identified in the literature include declining student interest, developing appropriate pedagogies, appropriate assessment, curriculum design, gender balance, social and cultural aspects, transition between various stages of formal education and bridging the gap between research and practice[1,2,3,4,5,6]. Three recommendations from the Nuffield Report are that:

- '*more attempts at innovative curricula and ways of organising the teaching of science that address the issue of low student motivation are required*'
- '*developing and extending the ways in which science is taught is essential for improving student engagement'*

- *'EU governments should invest significantly in research and development in assessment in science education'*

Although the Nuffield report relates to second level education, the recommendations are applicable at third level. Upcraft and Gardner[7] have also noted that the transition into university education has been identified as an area of difficulty for some students. They state that, '*Many students enter higher education environment with little preparation, having little idea of what to expect, and little understanding of how university can affect their lives'*. It is further noted that incorrect perceptions and expectations of university can lead to student underperformance and high student drop-out rates at university[8]. It is clear that many of the challenges in science education mentioned relate directly to the factors that influence student learning identified. This study investigates student profiles, based on the 'learner considerations' highlighted in Figure 1, where a 'profile' includes student's motivations, preparedness for university, expectations of university, interaction with learning supports and approaches to learning at university. The research questions that the first part of this study sought to investigate where:

1. *Do students interact with learning supports when provided and if so is there any correlation between student interaction and academic performance?*

2. *What is the profile of the first year students; how does the profile differ between the successful and the non-successful student? Is it possible to identify the key factors that impact on 'successes' in terms of examination performance? Finally, how does the profile of the first year student change as they progress into the next year of study?*

The second part of this study focuses on student learning through the teaching of undergraduate chemistry laboratories based on the teaching considerations identified previously. It is noted in the literature that the teaching of chemistry laboratories often does not provide the full potential of learning opportunities to students[9,10]. A chemistry laboratory module was introduced and evaluated at first year undergraduate level. The research questions relating to the second part of this study were:

1. *Can a broad range of skills (including technical, communication, observation, data manipulation, data interpretation etc.) and underlying chemical knowledge be learned through chemistry laboratories?*

2. *Can appropriate assessment be used to evaluate all aspects of chemistry laboratories and encourage student learning?*

3. *Can a learning environment that encourages student engagement and interaction with undergraduate chemistry laboratories be introduced with a large heterogeneous group of students?*

This thesis consists of four chapters; the first two chapters focus on student learning and student profiles at first and second year undergraduate chemistry. The second two discuss the introduction of a chemistry laboratory module. In Chapter 1 an overview of literature relating to student learning is presented. This literature will serve as a framework for this study, particularly relating to the generation of student profiles including student interaction with learning supports and student approaches to learning. In Chapter 2, the methodology and findings relating to the generation of student profiles will be given. This will firstly outline the pilot study concerning student interaction with learning supports and secondly will discuss the generation of student profiles which followed the pilot study. In Chapter 3 an overview of literature relating to undergraduate chemistry laboratories will be highlighted. Additionally, the aims of the laboratory module introduced and actions used to achieve these outlined aims and implementation are detailed. In Chapter 4, findings relating to the evaluation of the introduction of the laboratory module are discussed. Finally, overall conclusions are presented to address the research questions posed in this introduction. Future work and recommendations are also discussed.

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Chapter 1:

Literature Review on Student Learning

The ultimate aim of this work is to gain insight of and to improve student learning in a first year university undergraduate chemistry programme. If one is to improve student learning, an understanding of how, and why, students learn is important. This chapter gives an overview of literature relating to these two areas. The question of how students learn will be looked at first. This will be followed by a discussion regarding the factors that influence learning. The overview will serve as part of the framework for both the generation of student profiles and implementation of a chemistry laboratory module as mentioned in the introduction.

1.1 Models of student learning

In this section, a selected overview on models of how students learn will be presented. The information processing model will be discussed in detail, as it is this framework for 'how students learn' that informs this study. The traditional approach to student learning has its basis in the Behaviourist School of Thought[1]. This approach is based on an input-output model, where what is 'input' has a dependent causal effect on the 'output' observed. However, what occurs in the middle is unknown (Figure 1.1).

Figure 1.1: Input-Output Model of Learning

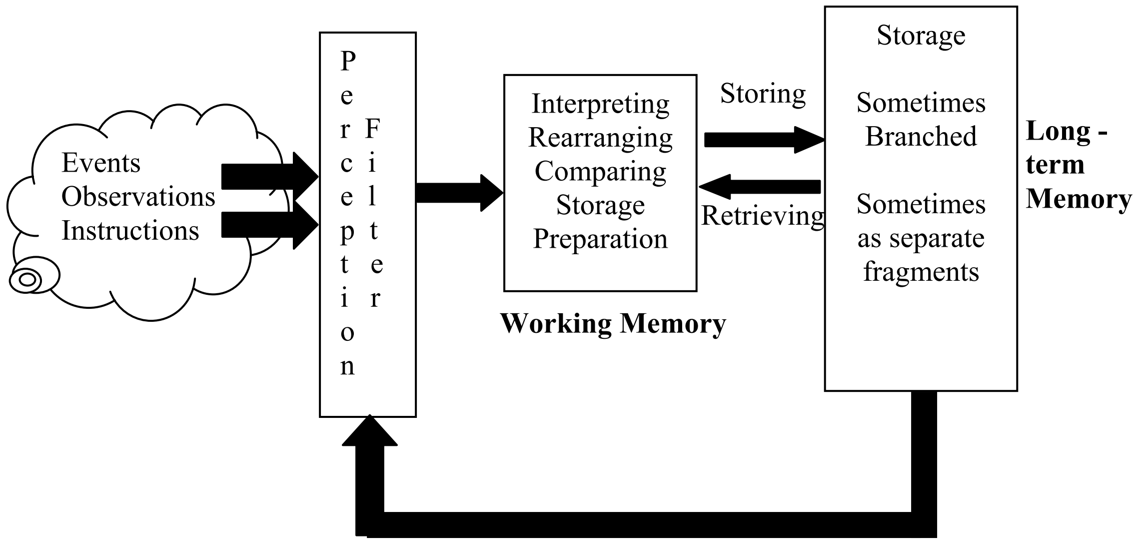
This traditional view was the leading model for learning in the early 20th century, and educators "regarded the input-output model as the only legitimate one since the input and output could be measured objectively and inferences and predictions could be made". This model did not take into consideration what happened inside the 'black box' since it was deemed to be "unnameable to scientific enquiry". The model also contained the hidden assumption that knowledge could be "transferred intact from the mind of the teacher to the mind of the learner"[2]. In the past 30 years, thinking has changed within the field of general education with regards to the question of how learning takes place and has shifted towards a more cognitive view of learning. Piaget's theory of intellectual development was one of the first cognitive perspectives on learning, and it influenced new theories, including constructivism and information processing models.

Piaget (1896-1980), focussed his work on how the child's thought processes developed[3]. He examined the development of the child from birth (Development of Sensory-Motor Thinking) to adolescence (Emergence of Formal Thinking) in order to determine how children attain knowledge. He proposed that the learner develops mental structures or schemes into which all new knowledge fits. These schemes are sub-divided into three categories; physical, social knowledge and logico-mathematical into which all learning can be placed. Central to Piaget's theory are the notions of assimilation, equilibration and accommodation. Assimilation refers to the taking in of sensory experiences which learners encounter which they then assimilate into their pre-existing mental schemes. When learners come across something that they do not understand, or have not seen before, a problem arises, since the information cannot be fitted into a pre-existing scheme. When this occurs, they experience dis-equilibration. For this problem to be resolved, alterations of their pre-existing schemes must occur in order to allow the new data to 'fit' into their schemes. This processing or re-equilibration is known as accommodation. Piaget's theory proposes that a learners' previous knowledge is essential to future learning since new knowledge must be constructed to fit in with what is already present in their mental scheme, as "*the learner strives to organise his/her experiences in terms of pre-existing mental structures or schemes*". Piaget's theory has given rise to the constructivist theory, which Fry refers to as the most prominent theory regarding learning[4]. He states *"…learners construct understanding. They do not simply mirror and reflect what they are told or what they read. Learners look for meaning and will try to find regularity and order in the events of the world even in the absence of full or complete information…*"; thus reflecting Piaget's development theory in which children seek ways to 'fit' new knowledge into their pre-existing mental schemes.

Vygotsky (1896-1934), a social theorist, acknowledges a constructivist approach but proposed that learning is better achieved in a social environment[5]. Vygotsky notes that "every function in the child's cultural development appears twice: first, on a social level, and later, on the individual level; first between people (interpsychological), and then inside the child (intrapsychological)[6]. This applies equally to voluntary attention, to logical memory, and to the formation of concepts. All higher functions originate as actual relations between human individuals". Vygotsky's most noted contribution to education is the idea of the Zone of Proximal Development (ZPD)[7]. This examines the child's mental development in relation to problem solving at an individual level, and then with assistance of a more able other. It was observed that children who had the same reading and chronological age could still be at different stages of mental development. Thus they could have varied problem solving abilities. When assisted by a facilitator, their problem-solving abilities could be increased to varying levels. Thus ZPD infers that it is essential that student-centred problem solving is provided and that educators are aware of the different mental development stages of the students, and that tasks used are designed with this knowledge.

Thus far learning has been presented as 'fitting' new knowledge to pre-existing knowledge, but the question remains of how does this take place? Learning is idiosyncratic in nature in that we all construct our *own* system that fits or works with the reality we observe, and *our* previous mental schemes. This implies that even though an outcome may be the same, the actual understanding or knowledge that students have may be different. This may partly explain how misconceptions arise in student's knowledge. Misconceptions may be due to 'misfits' when knowledge is being constructed, as until a constructed knowledge is proven to be useless, it will remain as the understanding for a given topic. According to Bodner, "*The concepts, ideas, theories, and models we construct in our minds are constantly being tested as a result of our experiences, and they survive in a pragmatic or instrumental sense only as long as they are useful*". Kuhn notes that "*the only way to get rid of an old theory is by constructing a new theory that does a better job at explaining the experimental evidence or finds a more appropriate set of experimental facts to explain. The only way to replace a misconcept is by constructing a new concept that more appropriately explains our experiences*"[8] and the evidence shows that once students have constructed ideas it is extremely difficult for them to change them[9,10]. Various information processing models have been developed to explore how learners process and store information[1,11,12]. The models are intrinsically the same but sometimes use different terminology. One information processing model is presented in Figure 1.2.

Figure 1.2: Information Processing Model from Johnstone[1]



There are three key elements to the model, (1) perception filter, (2) working memory and (3) long term memory (LTM). The three elements are closely linked and their interplay influences how students learn and the effectiveness of learning.

The perception filter determines how learners screen and select sensory information. It is a necessary element since learners are exposed to many pieces of information at any given time and it would be impossible to accept them all. How learners select information is based on previous knowledge already stored in the LTM. Previous knowledge and experience determines the information deemed relevant, important or interesting, supporting the idiosyncratic nature of learning and emphasising the importance of previous knowledge. This is supported by Ausubel's who says, "*the most important single factor influencing learning is what the learner knows. Ascertain this and teach him accordingly*"[13].

The working memory is the part of the brain where information is processed / reconstructed so as to fit with previous schemes and thus made ready for 'filing' in the LTM. There is a consensus that working memory has a limited processing capacity of 7±2 chunks of information and that the capacity of the working memory is genetically fixed, and develops until the age of 16 and also that the rate at which it develops is related to learning progress[14,15]. A chunk is a unit of familiar information to which the input is organised. The chunk is personal to the individual learner, and dependent on organisation skills and previous knowledge. Due to the limited capacity of the working memory, when new information is being processed, it displaces information already being stored there. How new information is accepted into the working memory is dependent on previous knowledge and an individual's ability to structure and organise the information into chunks that link to previous knowledge. Thus the ability to process/organise new inputs into chunks is important when learning, as it allows one to deal with more information.

Johnstone and El-Banna have investigated how working memory capacity can be used to predict test performance[16]. They proposed a simplified model of the working memory which has three elements; (1) the task demand, e.g. complexity of a question or learning topic, (2) the working memory capacity and (3) the strategies that a learner uses to cope/organise the new information. According to the model successful learning or indeed problem solving can take place if the task demand is lower than the working memory of the student, although this is not a 'sufficient condition', other factors such as previous knowledge and motivation can impact on learning which will be discussed later in this chapter. Success is deemed to be less likely if the task demand is greater than the working memory capacity; in this situation the person will experience an information overload and struggle with the demand of a task unless they possess strategies, previous knowledge or tricks so that demand of the task can be re-organised to the point where it becomes less than the working memory capacity.

In their study, they measured working memory capacity using two tests, the 'digits backwards test' (DBT) and 'figure intersection test' (FIT), and only students who scored identical working memory capacity scores on both tests were considered. The working memory capacity values were compared to students' responses on examinations where task demand values had been previously determined for each question. The study showed that level of success in answering questions drastically dropped once the task demand surpassed the working memory capacity; however in some cases students were able to do tasks beyond their measured capacities. These deviations were explained from interview data where students indicated their teacher had previously shown them a ‘dodge’ or strategy for coping with the some of the questions asked. Overall, it was found that students with a higher working memory capacity generally did better on the examinations, and that many of those with lower capacities did not make it into the 2nd year of university studies. In some cases however, students with a lower working memory capacity outperformed students with a higher working memory capacity, showing that students can perform beyond their capacity if they have effective strategies.

Johnstone and El-Banna note that knowledge of how our working memory operates must inform our teaching. They suggest that:

- When starting learning, the demand must be within the capacity of the learner;
- Teachers, as well as teaching content, must teach strategies and aid students to develop their own strategies so they can tackle tasks of higher demand and still be within the scope of their working memory capacity;
- Care must be given to ways in which concepts are interlinked so appropriate strategies can be developed.

Several studies have been carried out using this information processing framework that show similar observations of the impact of working memory on learning and performance[17,18,19,20].

The LTM is the third element of the information processing model (Figure 1.2). It is where information is ultimately stored. The effectiveness of the perception filter and working memory is related to how it forms links with the LTM and indeed how information is stored, thus it is pivotal in the successful construction of knowledge. Kirschner actually defines learning as a change in the LTM[21]. Johnstone suggests that there are four methods for storing information, all of which have different outcomes as shown in Figure 1.3[22].

Figure 1.3: Methods for storing information from Johnstone

Input Method		Storage Method		Learning Outcome
(A) Correctly constructed information	→	Fitted to existing knowledge	→	Enriches existing knowledge
(B) Correctly constructed information	→	Fitted incorrectly to previous mental scheme	→	Leads to misconceptions
(C) Linear construction of information (Lecture Series)	→	Stored in linear fashion; unable to crosslink or relate to previous knowledge	→	Only able to answer questions that follow same linear pattern as constructed information
(D) Memorisation	→	Unlinked to previous mental schemes	→	Unsuccessful learning that does not permit application of information

From Figure 1.3, it is shown that the quality of learning is related to the delivery of information as well as the storage method. For example, in method (C), where information is presented in a linear fashion, perhaps in a lecture series or text book, a learner will store the information in the same format, thus will only be able to access the information in the same linear fashion. This means that the information is not linked to other knowledge and later it is more difficult to access and to relate to other pieces of knowledge rather than if had been presented in a manner that made relevant cross links between the information provided. Reid notes that those who have stored information in a highly linked matrix of ideas, can more readily access the information later much more easily and that conceptual understanding is dependent on the ways ideas are linked to each other in meaningful patterns[23]. The importance of linking is also advocated by Gagné and White[24]. Ausubel has distinguished the difference between method (A) and method (D) as being the difference between “meaningful” and “rote learning”, where meaningful learning is learning in which “new information is attached to existing learning, making it more interconnected and accessible through many cross references”[25].

Another cognitive idea that influences learning is that of field dependence and field independence, which is sometimes referred to as disembedding ability, and is an element of the perception filter. The idea was originally developed by Witkin *et al*[26,27]. It relates to a learners’ ability to identify relevant material from excess information. Students who are field independent are better able to extract relevant material than field dependent students. It has been found that disembedding ability generally correlates with academic performance[19,20, 28].

In summary, it is suggested that five key elements affecting learning include: (1) learners’ previous knowledge, (2) how learners perceive information, (3) how learners construct new knowledge, (4) how learners store knowledge and (5) the interplay between working memory and LTM (where information is stored). These cognitive perspectives of learning do not present the totality of factors influencing learning. As mentioned, there are other affective factors such as motivation, interest and learning environment that also play an important role and will be discussed in the next section. However, an awareness of how students learn is essential to inform how we should teach and can improve student learning. “*If we want to have meaningful learning, our teaching has to create the atmosphere and the opportunity for such learning to take place*”.

Johnstone has devised 10 statements towards influencing student learning that address this overview and he notes some implications to be considered for teaching (Table 1.1). In Table 1.1 it is observed that some of the statements are directly linked to findings from the cognitive view of student learning and the information processing model. Some of the statements, however, relate to affective factors that can influence student learning such as confidence, motivation and interaction with teachers and learning environments. In Section 1.2 these ‘factors that influence learning’ will be discussed further.

Table 1.1: Statements towards influencing student learning from Johnstone[22]

Johnstone's statements	Factors
1. What you learn is controlled by what you already know and understand.	Cognitive
2. How you learn is controlled by how you have learned successfully in the past.	Cognitive Affective
3. If learning is to be meaningful, it has to link on to existing knowledge and skills enriching and extending both.	Cognitive
4. The amount of material to be processed in unit time is limited.	Cognitive
5. Feedback and reassurance are necessary for comfortable learning, and assessment should be humane.	Affective
6. Cognisance should be taken of learning styles and motivation.	Affective
7. Students should consolidate their learning by asking themselves about what is going on in their own heads	Cognitive Affective
8. There should be room for problem solving in its fullest sense to exercise and strengthen linkages.	Cognitive Affective
9. There should be room to create, defend, try out and hypothesize.	Cognitive Affective
10. There should be opportunity given to teach (you don't really learn till you teach).	Cognitive Affective

1.2: Factors influencing student learning

In Section 1.1 an overview of theories regarding how students learn has been presented and a discussion of the information processing model and implications for teaching based on cognisance of the model have been highlighted. It was noted that the 'cognitive' perspective on learning is just one aspect and that a more complete view of learning must also consider 'factors which influence learning'. In this section an overview of literature relating to factors influencing learning will be given.

There are many conceptualisations of student learning[29]. Theories of student motivation and students' perspectives on learning and teaching and also their approaches to learning often form parts of these conceptualisations[30]. In Figure 1.4 a conceptual framework indicating influences on student learning as proposed by the Enhancing Teaching-Learning Environments in Undergraduate Courses (ETL) Project is provided[31]. "Quality of learning achieved" is the central focus of the framework which is divided into two sections; the upper section of the figure relates to variation in students including existing knowledge, understanding, abilities, motives and conceptions/styles of learning, students' perception of learning environments and the approaches they adopt to learning and studying. The lower section of the figure highlights teacher-centred influences including selection, organisation, presentation and assessment of course material, design and implementation of teaching-learning environment, the expectations of what students are to learn and understand and teachers' way of thinking about teaching. The arrows in the figure indicate that some of these influences are interlinked e.g. there is a two way connection between teachers ways of thinking and both the design and implementation of course material and the selection, presentation, and assessment of the material. Similarly it is seen that students' approaches to learning are influenced by the presentation and assessment of the material. It is clearly evident that many of the factors proposed are addressed in Johnstones' statements previously mentioned (Table 1.1) e.g. in statement five, Johnstone notes that feedback and assessment are important for learning. Student motivation, approaches to learning, expectations and perceptions of teaching and learning at university, and assessment, are core elements of the ETL framework on student learning. These specific areas are also important elements of the investigation into student profiles and the implementation of learning supports and a chemistry laboratory module carried out in this work. In Figure 1.5, the specific factors relating to student learning investigated in this study are summarised. In the next section, selected literature relating to these factors will be discussed as a framework for this study.

Figure 1.4: Conceptual framework indicating influences on student learning from the ETL[31]

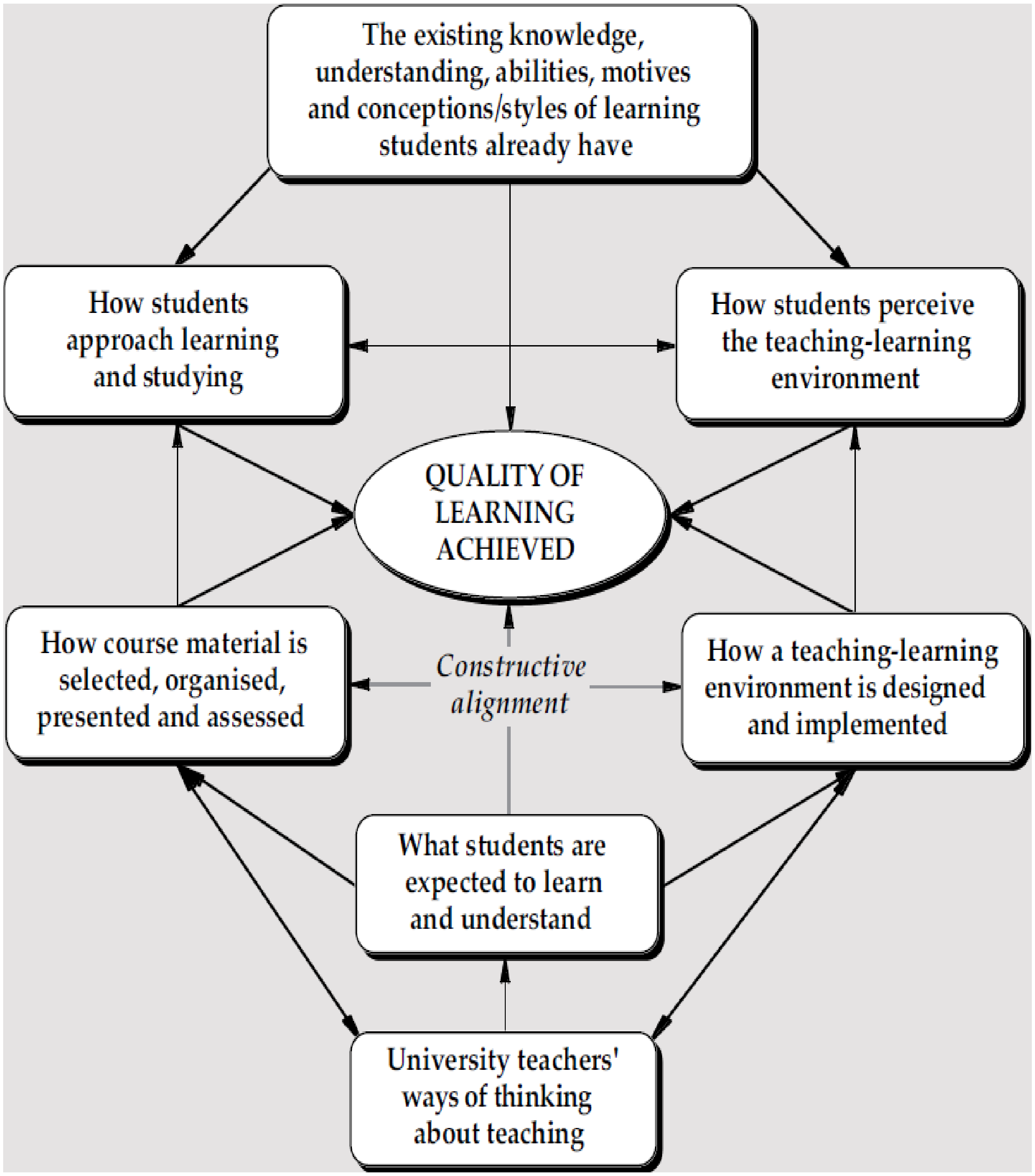


Figure 1.5: Factors influences student learning investigated in this study

- **Learner Considerations**
  - Previous knowledge / learning experiences
  - Motivation
  - Interaction / engagement with learning supports
  - Expectations of learning / learning supports
  - Perceived preparedness
  - Approach to learning
- **Teaching Considerations**
  - Overall aims
  - Learning environment
  - Assessment procedures

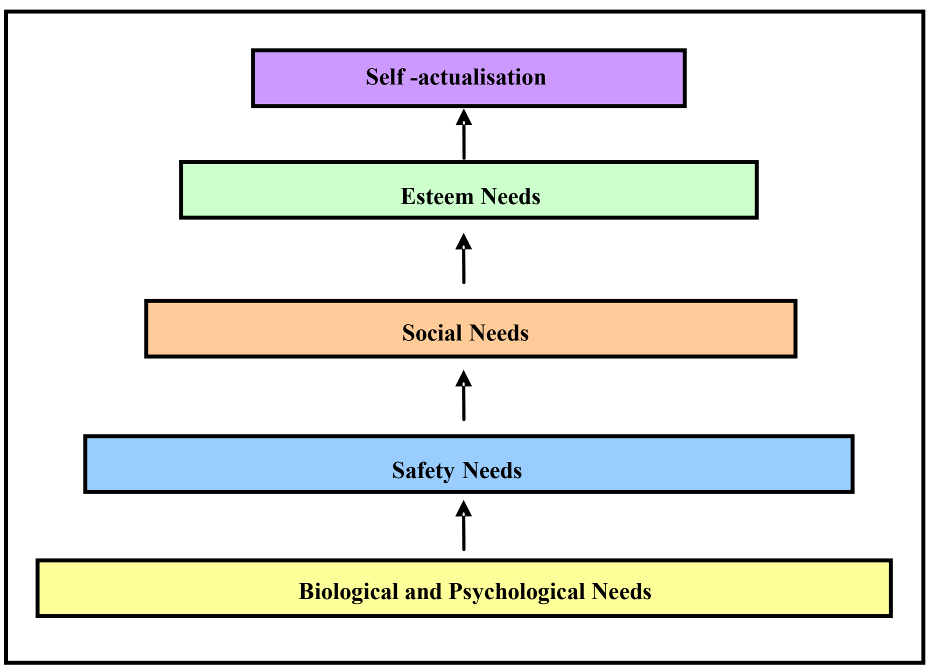
1.2.1 Student Motivation

"*Motivation is a concept which has been used by both psychologists and educationists to explain differences among learners in the amount of effort they put into their learning*"[32]. A broad view of motivation categorises it into two types dependent on the source of the driving force. Intrinsic motivation is where there is an inherent (personal) desire or interest in a task and extrinsic motivation relates to situations where external factors create the driving force for doing a task. Many of the early theories on motivation originate from a behaviourist perspective. Like behaviourist theories on student learning, early views held were that motivation arose from external influences i.e. in terms of a reaction to an external reinforcement. Humanistic and cognitive theories have since been presented which offer a different view of the origins of motivation and will be discussed in this section. There are merits to all of these theories but "*no single theoretical interpretation of motivation explains all aspects of student interest or lack of it*"[33]. Over the past 40 years there has been much research into the relations between motivation and student participation, learning environments and methodologies for teaching. A general overview of the theories on motivation will be presented here in the context of student learning though many of the theories transfer to almost every daily activity.

The Behaviourist Theory of human behaviour was developed from observations of behaviour in animals and how it could be manipulated by particular reinforcements. The theory proposes that the type of reinforcement that a student is exposed to determines the behaviour displayed, and thus by understanding this link appropriate reinforcement contingencies can be developed to influence behaviour and learning. *"Any condition or event which can be shown to have an effect upon behaviour must be taken into account. By discovering and analyzing these causes we can predict behaviour; to the extent that we can manipulate them, we can control behaviour"*[34]. Skinner notes that looking for other influences on motivation that are inside the body such as neural and psychic inner causes can be dangerous and misleading, and can sometimes lead to properties being assigned to inner explanations without just cause. "*The practice of looking inside the organism for an explanation of behaviour has tended to obscure the variables which are immediately available for scientific analysis"*. Skinner examines different methods of reinforcement contingences in terms of frequency and type of reinforcements. He notes that the reinforcement used is dependent on the behaviour that is sought, but specifically notes that reinforcers such as career and money are poor reinforcements regarding the development of motivation since they relate to ultimate end goals and are not immediate; *"But this* (trying to make ultimate goals affective) *is a rather crude use of conditioned reinforcers which, being derived from ultimate consequences, are unfortunately weak"*[35]. The criticisms of the behaviourist approach are that it promotes extrinsic motivation and is detrimental to intrinsic motivation since it relies heavily on external rewards. When adopting a competitive nature to the obtaining of rewards, where only a small number of people obtain a reward for completing an outcome, the approach can diminish people's feelings of self-worth and as a result be detrimental to their future learning. While there are criticisms of this approach it does have some merits. It has been shown that the use of appropriate rewards can influence behaviour in a positive manner and promote intrinsic motivation. It is suggested that if rewards used are attainable for all and supported by verbal feedback, intrinsic motivation can be promoted[36,37].

The humanistic view of motivation was developed by Abraham Maslow in 1940s[38]. He developed a theory based on a hierarchal system of 'needs' (Figure 1.6). Maslow outlines that humans have five main needs starting with physiological needs (such as food and oxygen – necessities for life) and rising to the need of self-actualisation (the need to meet ones capabilities and aspirations). The basis of his hierarchal system is that in order for a person to achieve the 5th need 'self – actualisation', they must first satisfy the lower needs. The hierarchal system splits into two types of needs, deficiency and growth. The deficiency need represents the first four elements of the pyramid. The basis for the division is that when there is a deficiency e.g. being hungry, then the motivation to satisfy the need arises, whereas the growth need for self-actualisation is one which people constantly attempt to fulfil. Maslow has identified two further needs not present on the hierarchal system, cognitive needs (knowledge) and aesthetic needs (order and harmony). He notes that both of these two needs must be satisfied before self-actualisation can be achieved.

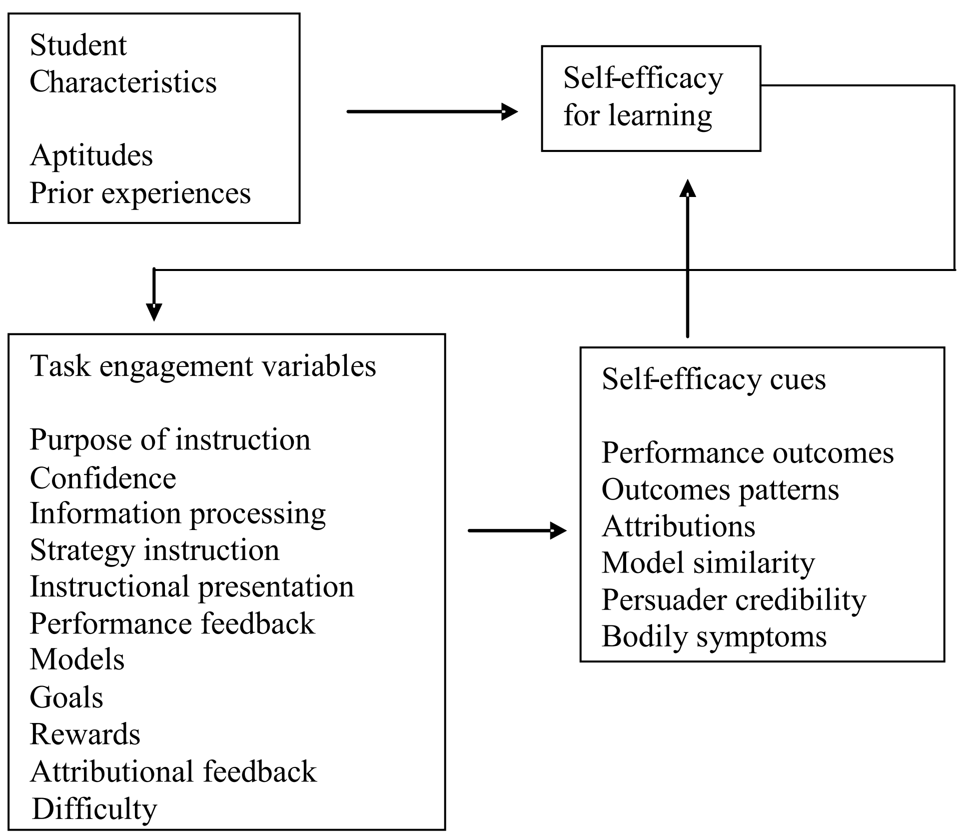
Figure 1.6: Hierarchy of needs adapted from Maslow



In the social cognitive perspective, there are three main factors that influence people's drive, namely 'behaviour', 'cognitive', and 'personal and environment' factors. Each of these is seen as an interacting determinant on the other two[39]. In the context of student motivation for learning, two main views exist for this perspective, (1) models and (2) self-efficacy. In this context, 'models' relate to situations that may or may not affect motivation. A model could be a student studying hard and achieving good results or receiving verbal praise from a teacher. The observation of a model and the outcomes of that model may motivate a student to imitate the action in order to receive the same reward, "*seeing others rewarded or punished, functions as a motivator by arousing expectations in observers that they, too, are likely to experience similar outcomes for comparable performances"*. It must be noted that students must value the outcome of the action if motivation is to occur i.e. if they place no value on receiving praise from a teacher, then observing this may not generate motivation.

Self-efficacy is a persons' perception of their own ability to complete a certain task. Bandura notes the importance of self-efficacy when discussing vicarious reinforcement; "*knowing what outcomes result from a given action is unlikely to spur observers to action if they doubt they can do it. Thus, motivation is also mediated by self-percepts of efficacy…..people mobilise greater effort and persist longer on a task if they are confident they can do it than if they judge themselves to be inefficacious*". There are many factors that can affect self-efficacy such as previous learning experience and social interactions[40]. These in turn can influence the learning process that students adopt, students' expectations, the goals students set themselves, and reasons that students give for their success or failure with respect to task. In Figure 1.7, a model of motivated learning is presented which highlights the role of self-efficacy[41]. As mentioned self efficacy can influence the type of goals that students set for themselves. Three types of goals that students may adopt are avoidance goals, performance goals and mastery goals. The type of goals that students choose can influence how they tackle a task. Avoidance goals are generally adopted by students of low self-efficacy and who achieve low grades. It relates to occasions where students choose to do anything but the task in hand, i.e. not studying or staring out a window in class. Students will often choose this type of goal in order to "be able to blame poor performance on the circumstances rather than on one's ability"[42]. Performance goals are generally adopted by students with high self-efficacy and who achieve grades. Those who choose performance goals often desire to boost their ego. They choose these goals in order to show off their academic ability to their peers and tutors and thus these goals have been referred to as ego goals and self-enhancing goals. Mastery goals (or learning goals) are also chosen by students who achieve high grades and have a high level of self-efficacy. These students choose this goal in order to understand a task. The difference between those who choose mastery goals and performance goals, is that the latter are not terribly concerned with understanding the topic as long as they can demonstrate their superiority of the task, perhaps in a test. To achieve this they may rote learn sections of the topic without actual understanding. Since those who choose performance goals are seeking to boost one's status amongst their peers they often outperform students who choose mastery goals; "*Students adopting mastery goals were more interested in the class, but students adopting performance goals achieved higher levels of performance*"[43].

Figure 1.7: Model of Motivated Learning from Pintrich & Schunk[41]



Attribution theory examines motivation to learn in the context of students' reasons for their success or failure[44]. It is closely linked to self-efficacy. Successful students (high self efficacy) tend to attribute success to ability and effort applied, and failure to lack of effort, whilst unsuccessful students (low self efficacy) attribute success to external factors, 'simple tasks' and 'luck' and failure to a perceived stable attribute, 'lack of ability'. For the successful student the attribution of 'failure' to effort is beneficial in that effort is within their control and thus failure can be an instigator to apply more effort. However, the attributions of the less successful student is concerning as it is associated to external attributions outside of the learners' control, and failure is associated with a perceived stable attribution i.e. 'ability', which doesn't change, hence it is difficult for the student to see a 'way' to improve their level of achievement. The attributions of the low achiever are generally a result of a history of low achievement which can result in low self efficacy.

When discussing 'models' and 'self efficacy' it was noted that students need to value an outcome to be motivated by it. This is the basis of expectance value theory[45]. This theory notes that the motivation a student will adopt is dependent on the value the student associates with the task and his/her expectation for success. Those who place more value on a task i.e. have a higher need for achievement will tend to have a greater expectation of success than those who have placed a lower value on a task. In the context of student learning, expectance value theory could explain motivation variations observed in students studying subjects that may not be part of their major subject. It could also be a justification for assessing all aspects of courses taught i.e. if there is a value placed on a given area by an assessment component, it may increase students motivation towards the area.

Interest theory relates to a persons predisposition and psychological state where the "*psychological state is characterized by focused attention, increased cognitive and affective functioning and persistent effort*"[46]. There are three elements pertaining to interest theory, situational, personal and topical. Situational theory refers to a type of interest that is temporary and brought about through a context that may be of personal interest or something that causes a cognitive conflict[47]. This interest usually ends when the situation has ended, though in some cases it does persist. A person with a personal interest "*seeks opportunities to engage in associated activities and while so engaged experiences enjoyment and expands his or her knowledge*". Personal interest in contrast to situational interest is where a more persistent interest takes place and can occur due to a number of reasons such as culture, emotion, competence, personal relevance, prior knowledge or a gap in prior knowledge. Personal interest can be developed by past experience i.e. in the learning context, if a person feels they are good at a topic or conversely if they are anxious about a topic, these feelings will influence whether they will have a personal interest in it or not. The degree of personal interest brought to a task has been shown to affect intrinsic motivation for that task[48]. "*Topic interest refers to the interest elicited by a word or paragraph that presents the reader with a topic"* . It relates to the interest aroused based on the students expectations of what the topic will involve.

Cognitive development theory relates Piaget's theory of equilibration, assimilation and accommodation to the constructivist view on information processing. As mentioned previously, Piaget proposed that the learner develops mental structures or schemes to which all new knowledge fits. The innate desire for organisation and order is the basis for the cognitive development view of motivation where "*the learner strives to organise his/her experiences in terms of pre-existing mental structures or schemes*"[49].

Theories on motivation discussed above have concentrated on identifying factors that promote or diminish motivation. Motivation has been considered in terms of intrinsic or extrinsic motivation, and factors identified in each theory will direct the students towards either one of these motivations. Self-Determination Theory (SDT), proposed by Deci and Ryan, is a more recent theory on motivation and was introduced during the mid 1980s[50]. SDT examines the idea of a continuum of motivation levels rather than the two separate types. It looks at motivation in terms of the level of which it is self-determined or self-regulated[51]. The continuum has six regulations (or perceived value) i.e. non-regulation, external regulation, introjected regulation (where behaviours are performed to avoid guilt, anxiety or to attain ego enhancements such as pride), identified regulation, integrated regulation and intrinsic regulation which are differentiated by the amount of internalisation of a task on behalf of the learner. The non-regulation component of the self-determination continuum is also known as amotivation and represents a "*state of lacking the intention to act*". External regulation, introjected regulation, identified regulation and integrated regulation refer to varying levels of extrinsic motivation. The final regulation, intrinsic regulation, corresponds to intrinsic motivation. The SDT is being used as a framework to determine factors that link to each of the levels of motivation in order to promote increased internalisation and self-regulation by learners[52].

In this section an overview of theories relating to motivation has been presented. In this study students' motivations for entry to university will be examined and discussed in Chapter 2. Students' motivation towards various aspects of the laboratory module introduced will be discussed in Chapter 4, although no specific tool to analyse any of the theories of motivation have been used in this work. In Section 1.2.2 the overview of theories relating to motivation will be expanded upon in relation to students' approaches to learning.

1.2.2 Student Approaches to Learning

In Section 1.2.1, factors contributing to a students' motivation for learning were discussed e.g. previous learning experiences, self-efficacy, perceived value and expectation of success, interest etc. It has been noted that motivation is only one element of learning, where it relates to the intention on behalf of the student. Having identified these factors researchers have sought to investigate links between motivation and academic success. In the 1960s, studies were carried out in the USA and Britain to examine these links[53,54,55]. In these studies, motivation was determined using verbal reasoning scores. Positive correlations between motivation and academic success irrespective of ability were noted. Entwistle noted in his analysis of student performance that students were achieving similar grades but were using different processes to achieve them. Marton and Säljö also observed that the processes students used to achieve learning were important. They were the first to introduce the terms 'deep approach' and 'surface approach' where an approach to learning refers to the processes students adopt when learning[56]. Marton and Säljö carried out an investigation of students' learning processes when reading a given text. They noted that the 'approach' that students took in relation to the task influenced the outcomes of the task, and also that the outcomes were influenced by students conceptions of a task[57]. It was found that students had differing perceptions of what was expected from them and that these expectations influenced how they tackled the task and the subsequent outcome achieved. "Strictly speaking, there are two different aspects to an approach to learning. One is concerned with whether the student is searching for meaning or not when engaging with a learning task; the second is concerned with the way in which the student organises the task"[58]. The first aspect of the approach is subdivided into deep and surface approaches. Ramsden distinguishes the two as learning for real understanding (deep) versus imitation (surface). A deep approach refers to active engagement with a task in order to obtain meaning, i.e. when students intend to relate with the task in a manner that will allow them to understand the facts of the task in relation to real world concepts. A deep-approach leads to long-term learning and in-depth understanding. A distinction between deep and surface approaches have been made by other authors[59,60]. Marton & Säljö state that a deep approach "*is the best, indeed the only, way to understand learning materials*"[61]. A surface approach, on the other hand, refers to students' obtaining information in a random pattern for short-term recall. It is comparable to Ausubel's rote learning mentioned previously[62]. It has been referred to as "*a paralysis of thought*" and as an approach that is "*uniformly disastrous for learning*", that leads to an inability to relate knowledge to real world situations. Table 1.2 gives a detailed comparison of the attributes of both approaches.

The second aspect of an approach to learning examines the holistic and atomistic nature of learning and deals with how the learner organises learning material[63]. A holistic approach is one in which the student examines the material in full and interrelates all of the material, whereas with the atomistic approach material in accessed in a piecemeal fashion. In reality the two aspects of the approaches are interrelated and thus for this work the deep-holistic and surface-atomistic will be referred to as deep and surface approaches respectively.

Ramsden later introduced a third approach, called the strategic approach[64]. This is an approach "*in which the intention is to achieve the highest possible grades by using organised study methods and good time management. Interest in the content is typical of a deep approach, but the alertness to assessment requirements is typically strategic*"[65]. The strategic approach is similar to the 'achieving' dimension identified by Biggs[66]. Students' adopting strategic approaches tend to focus on time management, organising their study and monitoring the effectiveness of their study patterns in order to achieve high grades. However, as Biggs notes, this may correlate with good grades but it does not necessarily lead to long-term retention.

Tables 1.2: Attributes of deep and surface approaches to learning from Ramsden[58]

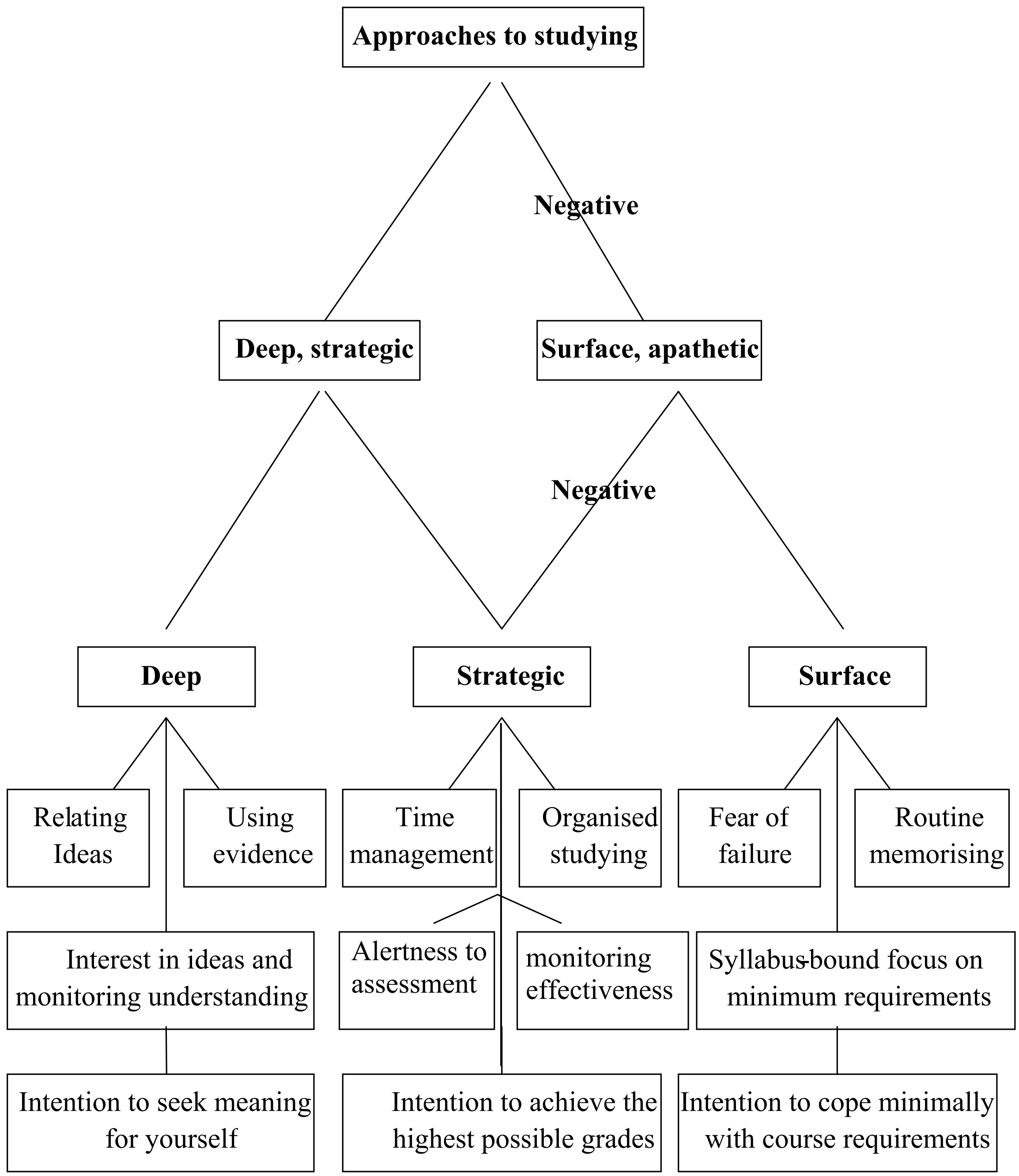
Deep approach *Intention to understand - Student maintains structure of task.* Focus on 'what is signified' (e.g. the author's argument, or the concepts applicable to solving the problem). Relate previous knowledge to new knowledge. Relate knowledge from different courses. Relate theoretical ideas to everyday experience. Relate and distinguish evidence and argument. Organise and structure content into a coherent whole. *Internal* emphasis: 'A window through which aspects of reality become visible, and more intelligible' (Entwistle and Marton, 1984)
Surface approach *Intention only to complete task requirements - Student distorts structure of task.* Focus on 'the signs' (e.g. the words and sentences of the text, or unthinkingly on the formula needed to solve the problem). Focus on unrelated parts of the task. Memorise information for assessments. Associate facts and concepts unreflectively. Fail to distinguish principles from examples. Treat the task as an external imposition. *External* emphasis: demands of assessments, knowledge cut off from everyday reality.

Having identified links using the verbal reasoning methods for analysing motivation, attempts were made to develop inventories to analyse students' approaches to learning. A variety of inventories have been developed internationally. In Australia, Biggs developed the 'Study Process Questionnaire' (SPQ); in the U.S.A, Schmeck developed the Inventory of Learning Processes (ILP)[67]; in the Netherlands, Vermut developed the Inventory of Learning Styles (ILS). In the U.K., the 'Approaches to Studying Inventory' (ASI)[68], which later became the 'Revised Approaches to Studying Inventory' (RASI)[69], and then the Approaches and Study Skills Inventory for Students (ASSIST)[65,70], were developed. More recently the Learning and Studying Inventory (LSQ) and Experience of Teaching and Learning Inventory (ETQL) have been developed, which investigate both students' approaches to learning and their experiences of the learning environments.

In this study, the ASSIST Inventory was used to measure students' approaches to learning towards chemistry and will now be discussed in more detail. The inventory has been used in several disciplines including medicine, pharmacy, accounting and science[71,72,73,74,75].

The inventory determines students' approaches by analysing their responses to statements relating to 13 different subscales. The subscales relate to each approach as shown in Figure 1.8. It can be seen that the subscales reflect the attributes of each approach as outlined in Table 1.2.

Figure 1.8. Components of the Assist Inventory adapted from Entwistle[65]



The deep approach is broken down into four subscales; namely, seeking meaning, relating ideas, using evidence and interest in ideas. The strategic approach is broken into 5 subscales; i.e. organised studying, time management, alertness to assessment demands, achieving and monitoring effectiveness, while the surface approach is split into four subscales; i.e. lack of purpose, unrelated memorising, syllabus-boundness and fear of failure. Each subscale is assessed by students' response to 52 Likert-scale statements. It is noted by Entwistle that the first-three subscales in each approach are most consistently related, and that the subsequent subscales can vary in their relationships depending on the sample being evaluated[76]. For example, in the strategic approach, the subscales, "organised study", "time management" and "alertness to assessment demands" are consistently related to the strategic approach, however, the subscale "achieving and monitoring effectiveness" is not always related to this approach.

The earlier discussions on motivation have identified many factors that also relate to the approaches students adopt in learning, e.g. in goal theory, comparisons can be made between mastery goals and a deep approach, performance goals and a strategic approach and avoidance goals with a surface approach. Interestingly, as seen in Figure 1.8, it is suggested that successful academic performance is best achieved through a combination of deep and strategic approaches without any components of a surface approach and from the goal theory perspective, jointly pursuing mastery and performance goals may prove to be a more successful motivational strategy than a sole focus on mastery goals in some educational contexts[77]. Ramsden refers to approaches to learning being very often misunderstood. It is commonly assumed that approaches are characteristic of an individual and their innate make-up, thereby implying that the characteristics of the student determine the approach taken. Indeed approaches are not related to the characteristics of students, that is to say that all students, regardless of their ability, can adopt either a deep or surface approach. Indeed students can take different approaches depending on the task and the environment surrounding the task, thus the approach is more a response to the learning and/or teaching environment. It is governed by the students' perception and previous knowledge of the task. The environment surrounding the task relates to such issues as task content, task perception, perceived expectations, task assessment, task delivery, task engagement process, anxiety and even departmental perceptions[78]. An acknowledgement and understanding of the various influences on learning approaches is essential in the provision of suitable learning environments for students, "*In trying to change approaches, we are not trying to change students, but to change the students' experiences, perceptions, or conceptions of something*". As noted in Figure 1.4, students' approaches to learning are influenced by many factors including knowledge abilities, motives, perception of teaching and learning environment, course material, assessment etc. In Section 1.2.4 a further discussion regarding the influence of assessment on approach will be given. In Chapter 2 the implementation of the ASSIST inventory will be discussed in more detail.

1.2.3 Expectations and perceptions of first year university

In Figure 1.4, it is observed that students' perceptions of teaching-learning environments influence their approaches to learning, their motivation and ultimately the quality of learning achieved. This relationship between student learning and perceptions of teaching-learning environments is apparent in the published literature regarding the transition into university. It is reported that both student drop-out and underperformance is related to incorrect perceptions and expectations of university[79,80,81]. Some students can find the transition into university particularly challenging[82,83]. McInnis notes that social, emotional, health and financial factors all influence students engagement with university[84]. In addition to these personal factors many authors note that there appears to be a mismatch between students' expectations of the university learning environment and the reality experienced and also that some students are ill-prepared to adjust to university study[80,81,85,86,87,88]. Ozga notes that "*students' perceptions of higher education tended to revolve around stereotypical assumptions such as they assumed moderate academic demands compared to A-level courses and the 'extremely exciting' social life"* . Many studies note that students expressed low expectations of work commitments[81,86,88]. There are also reports indicating students are unprepared for the different teaching environments in university such as large class sizes and lecture format. Byrne and Flood note that students indicate they are prepared for working independently but that this appears to be the biggest challenge for students. They note that students struggle with the lack of monitoring and control which they have been used to at second level. Cook and Leckey have found that students have poor study techniques when starting university especially in the areas of time management, reading around lecture material, note taking, asking questions in large groups, and working in teams. They further note that students' study habits from school persist during first year university and that they prefer teaching styles similar to those experienced in second level, "*Students have come to value a simple approach in which staff present classes with precise* *information which can be easily translated into examination answers and assignments*". It is generally accepted that the initial weeks in university are the most crucial in terms of retention of students, but also in helping to improve the quality of learning. In many universities there are introductory courses and online supports available to help students make the transition from second level[89,90]. Some reports on interventions have shown that participation on such courses can be beneficial in terms of improving students' academic performance[91,92]. In this work, student profiles based on students' reasons for coming to university, perceived preparedness, expectations of university life and study and students' approaches to learning have been generated to investigate how students engage with first year undergraduate chemistry. The results obtained will be discussed in Chapter 2 and comparisons made with those mentioned in this review.

1.2.4 Assessment and Learning

Assessment is an integral part of teaching and learning. Links between assessment and expectance value theory, approaches to learning, and the overall quality of student learning, have been mentioned previously in this chapter. Danili & Reid state that "*teaching and assessment are inseparable in the learning process and that assessment does not stand outside teaching and learning but stands in a dynamic interaction with them*". Studies in the USA and UK in the early 70s noted that assessment influenced students more than teaching and that their students' attendance and working habits were based primarily on assessment demands[93]. Assessment is multifaceted; it is used for grading and classification of students, as a tool to evaluate learning and teaching effectiveness (with other supporting data), to help future learning and to develop students self-assessment skills which are valuable in the development of life long learning.

There are a wide variety of assessment formats that can be used including traditional exams, reports, essays, portfolios, presentations, open book exams, peer assessment and indeed within these there are various methods and question types available. Recent reviews describes different assessment methods[94,95]. However, this discussion will highlight selected relevant literature on why we use assessment, and the impact of assessment on teachers, students and learning.

Why do we assess students?

There are many reasons why assessment is used which are summarised in Table 1.3. These reasons are listed under three headings; 'student learning, 'teacher learning' and 'institution classifications and requirements'. Six of these reasons focus on improving student learning. Boud has noted that, "*there is probably more bad practice and ignorance of significant issues in the area of assessment than in any other aspect of higher education*"[96]. However, looking at recent literature it appears that there is an increasing focus of research in the area of assessment, particularly with respect to formative assessment. Perhaps there is a challenge to disseminate this into Higher Education teaching.

Table 1.3: List of common reasons for assessing students at Higher Level adapted from Race

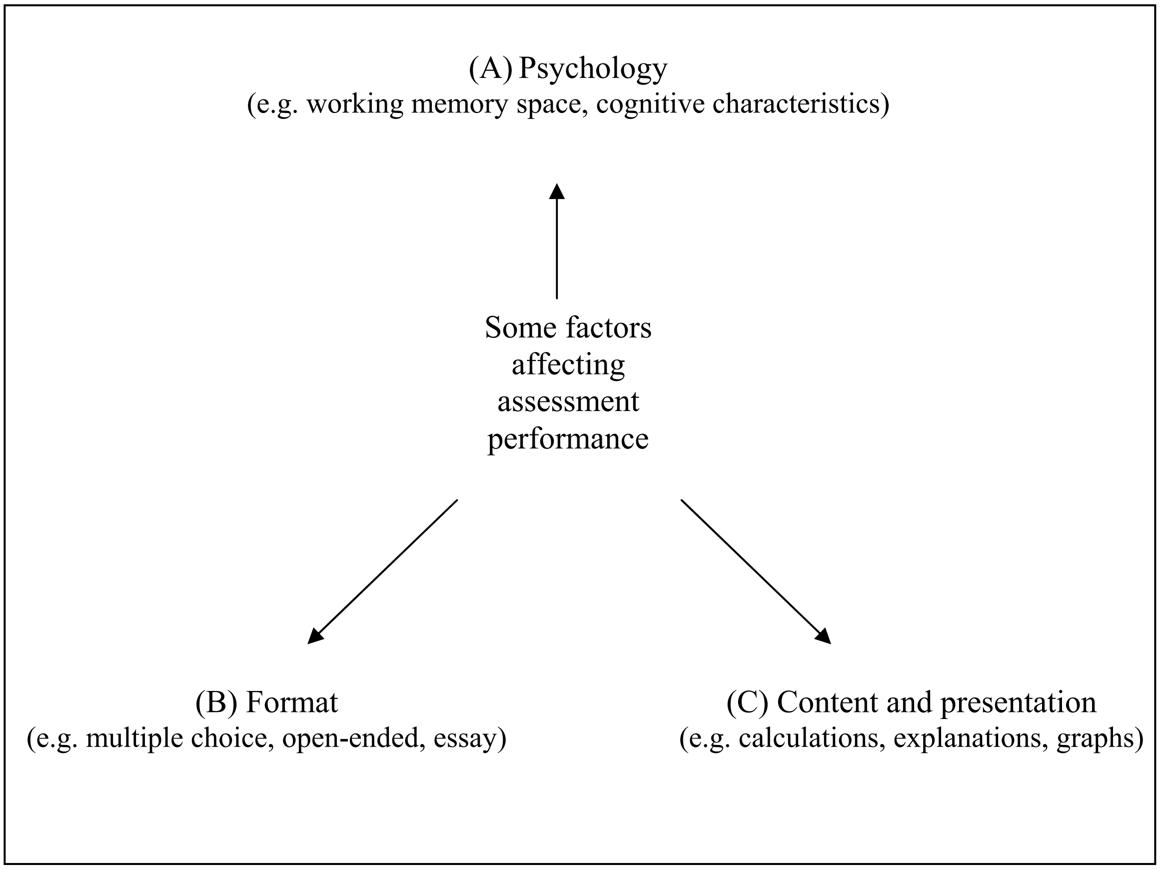
Reasons for assessment	**Focus**
To motivate students	Student learning
To enable student progression	Student learning
To guide improvement	Student learning
To facilitate students' choice of options	Student learning
To diagnose faults and enable students to rectify mistakes	Student learning
To add variety to students' learning experience, and add direction to teaching	Student learning
To give feedback on how teaching is going	Teacher learning
To classify or grade students	Institution
To provide statistics for the course or institution	Institution
To enable grading and final degree classification	Institution

There are guidelines of best practice regarding assessment design and implementation to be found within the literature[20,93,95]. In terms of using assessment as a measurement tool, Johnstone notes four factors that should be considered; validity, reliability, humanity and economy. He notes that for an assessment to be valid it should measure what it is intended to measure, and not something else e.g. a student answering a paper test on a practical experiment is not a measure of practical skills. Reliability refers to the reproducibility of the assessment results with the same students, or with a similar group of students taking the same course. Humanity relates to the duration and frequency of tests. He notes that too many tests, and tests that are too demanding in terms of length, can place too much pressure on students, both physically and mentally, which in turn can have many negative effects including underperformance and a decrease in motivation. The final consideration is economy, which refers to time and money. Johnstone notes that all assessment is expensive but the 'costs lie in different places according to the type of test'. The economy of a test can be looked at in three sections, setting, responding and marking. For example an essay style test would be expensive in terms of marking compared to a multiple choice test. A teacher must examine the economy of an assessment and decide on an appropriate test to be used.

Assessment formats

Questions regarding the validity of different assessment formats and what they actually assess have been raised by Danili and Reid[97]. In a recent study with upper secondary school children in Greece, they compared different assessment formats (multiple choice, short answer, and grid questions). They found that students performed differently on the various formats. Whilst students performed best on the multiple choice questions, they found that the order of merit on one format did not correlate with the order on another. Similar findings have been reported elsewhere[98,99]. In a follow up study they sought to investigate factors that may contribute to their earlier findings. They focused their attentions on two cognitive factors, field dependency and convergent/divergent factors. Field dependency has been previously discussed in relation to the information processing model. Convergent/divergent factors relate to the work of Hudson, where convergent thinkers are noted as those that tend to focus in on looking for the one right answer whereas divergent thinkers are better able to think on a wider scale and are more comfortable dealing with problems that may have several acceptable solutions[100]. Danili and Reid found that field dependency correlated with performance in assessments and assessment formats. However, convergent/divergent factors did not show the same correlations, particularly in relation to questions that differed in terms of amount of language and symbols used. In this situation convergent/divergent styles tended to correlate better for questions that primarily used words. Relationships between cognitive factors and performance on different assessment formats has been shown elsewhere[101]. Danili and Reid suggest that factors affecting student performance in assessment include (a) psychology, (b) format and (c) content and presentation (See Figure 1.9). These findings have implications regarding the fairness of assessments that we use e.g. by using a particular form of assessment, are one section of students favoured?

Figure 1.9: Some factors affecting student performance in assessments from Danili & Reid[20]



As discussed earlier, students' approaches to teaching and learning can influence their perceptions of assessments[102]. Students' who tend to adopt deep approaches tend to prefer assessments that allow them to express themselves and show their knowledge such as in essays or long answer style questions, whereas surface learners prefer formats such as multiple choice assessments. Also, the type of assessment used has an influence on the approach that students adopt[103]. Thomas and Bain observed that students' approaches to learning changed towards a surface approach when the assessment system was changed from essay format to multiple choice questions. They further noted that when they reverted back to the essay format, students' approaches also reverted back towards a deep approach[104]. Ramsden notes that students' explanations for adopting a surface approach were linked to the assessment used and similar findings have been reported by Entwistle and Tait[58,105]. Assessment is strongly evident in Ramsden's list of contexts that can lead to different approaches of learning (Table 1.4); indeed Ramsden and other authors have emphasised the need to utilise appropriate assessment methods and learning environments to encourage deep learning[58,106].

Table 1.4: Characteristics of the context of learning associated with deep and surface approaches from Ramsden

Surface approaches are encouraged by: • Assessment methods emphasising recall or the application of trivial procedural knowledge • Assessment methods that create anxiety • Cynical or conflicting messages about rewards • An excessive amount of material in the curriculum • Poor or absent feedback on progress • Lack of independence in studying • Lack of interest in and background knowledge of the subject matter • Previous experiences of educational settings that encourage these approaches
Deep approaches are encouraged by • Teaching and assessment methods that foster active and long-term engagement and learning tasks • Stimulating and considerate teaching, especially teaching which demonstrates the lecturer's personal commitment to the subject matter and stresses its meaning and relevance to students • Clearly stated academic expectations • Opportunities to exercise responsible choice in the method and content of study • Interest in and background knowledge of the subject matter • Previous experience of educational settings that encourage these approaches.

Formative Assessment and Feedback

Assessment that is used to help students' to correct errors and to inform past and future learning, and to assess teaching, can be termed formative assessment. There have been many studies and reviews illustrating benefits of formative assessment[107,108,109]. One of the most important elements of formative assessment is feedback. Yorke states that "without informative feedback on what they do, students have relatively little by which to chart their development"[110]. Brown says that, "*significant energy must be devoted to helping students understand not only where they have gone wrong, but also what they need to do to improve. They also need feedback when they have done well, to help them understand what is good about their work and how they can build on it and develop further*"[111]. Feedback can be given in a variety of ways, it can be formal or informal, teacher or peer driven. It can be in the form of a grade or comment, verbal or written. How feedback is provided is extremely important and can have either positive or negative consequences. This importance is evident in Maclellen's comparison of tutor and students perception on feedback[112]. Tutors believed that they were engaging in effective formative assessment however the students' perception was very different, "*most students did not view feedback on their learning as either routinely helpful in itself or as a catalyst for discussion… students primarily perceived assessment to be about judging levels of achievement rather than about enabling learning*". Hounsell reported that feedback is very often not read[113]. In Black and Wiliam's review it is reported that when feedback is in comment form only and a grade is not given, there is a greater tendency for a student to acknowledge the feedback and use it for future learning, however this is only possible when the comment is appropriate, for example a comment of "excellent" though perhaps encouraging does little to help learning. When a grade is given with a comment, students tend not to read the comment and only acknowledge the grade. The grade is perceived as a measure of ability and not to do with the task and again does not address learning.

Danili & Reid point to positive and negative implications of feedback in terms of motivation and self-esteem. It is important that the feedback given should consider the student characteristics. Bandura notes, "*the less individuals believe in themselves, the more they need explicit proximal, and frequent feedback of progress that provides repeated affirmations of their growing capabilities*"[114]. Yorke indicates the importance of feedback on transition to university and on retention rates within higher level, "*formative assessment contributes to academic integration, particularly as students come to terms with their transition into higher education. Indeed, without meaningful formative assessment, academic integration—and hence retention—is put at risk. Done well, and the student will flourish: done badly, and the risk of student discouragement or failure is increased—with a number of adverse implications ranging from learning that is less than optimal, through loss of income to the institution, and most worrying of all, the permanent inhibition of a student from taking the opportunity to grow through education*".

Peer assessment has been highlighted as a valuable tool to assist in providing effective feedback[115]. Peer assessment encourages students to think critically about assessment and to develop self-assessment skills which they may not develop if they do not have this opportunity. Boud notes that staff-driven assessment can actually be detrimental to students as it encourages 'learned dependence' where students concentrate on what they think the teacher wants them to do and not about what they know and whether they can or cannot do something, he states that "*too often staff-driven assessment encourages students to be dependent on the teacher or the examiners to make decisions about what they know and they do not effectively learn to be able to do this for themselves*"[116]. He argues that students need these assessment skills which are essential for 'sustainable assessment' and that this is important for independent learning[117]. This perhaps indicates that to limit this 'learned dependence', a variety of assessment formats should be used which encourage self-reflection, coupled with learning outcomes which emphasise all that has to be learned, including knowledge, skills and attitudes.

These issues regarding the importance of feedback highlight the need to develop criteria which constitute effective feedback. Guidelines to good practice in providing both assessment and feedback are available[93,94,110,118]. Recently, researchers (for the purpose of higher education) have attempted to develop theoretical frameworks for the provision of feedback and effective formative assessment that promote learning[93,110,118]. Gibbs & Simpson have developed a set of conditions under which assessment supports students' learning (Table 1.5) and Nicol & Macfarlane have made a list of seven principles of good feedback (Table 1.6)[93,118]. These frameworks seek to address the issues which have been mentioned thus far and act as a basis to which further research and appropriate assessment can be used within higher education.

Table 1.5: Conditions for assessment to support learning adapted from Gibbs and Simpson[93]

Conditions for assessment to support student learning	
1	Assessed tasks capture sufficient student time and effort
2	Students engage with the assessments; they allocate appropriate amounts of time and effort to the most important aspects
3	Tasks engage students in productive learning activity of an appropriate kind
4	Students receive appropriate feedback (amount and quality)
5	The feedback focuses on students' performance, on their learning and on actions under the students' control, rather than on the students themselves and on their characteristics
6	Feedback is timely in that it is received by students while is still matters to them and in time for them to pay attention to further learning or receive further assistance
7	Feedback is appropriate to the purpose of the assignment and its criteria for success
8	Feedback is appropriate, in relation to students' understanding of what they are supposed to be doing
9	Feedback is received and attended to
10	Feedback is acted upon by students

Table 1.6: Principles of Good Feedback adapted from Nicol & Macfarlane [118]

Principles of good feedback	
1	Facilitates the development of self-assessment (reflection) in learning
2	Encourages teacher and peer dialogue around learning
3	Helps clarify what good performance is (goals, criteria, expected standards)
4	Provides opportunities to close the gap between current and desired performance
5	Delivers high quality information to students about their learning
6	Encourages positive motivational beliefs and self-esteem
7	Provides information to teachers that can be used to help shape the teaching

Assessment in Higher Education

Within higher education, summative assessment predominates, with the main purpose being to grade and classify students. In this situation, the assessment may inform a lecturer of areas where teaching needs to be adjusted, but for the student it is often the case that the grade determined is the only form of feedback that they receive which does little, if anything, to inform them of misunderstandings, development of self-assessment skills or indeed direct them for future learning. Johnstone notes the use of a 50% pass mark is widespread across much of higher education. He questions the validity of using such a mark as an indicator of satisfactory course mastery, when assuming that all of the questions cover the claimed learning outcomes, a student is only competent in half of the material, and in many situations examinations contain choices so a 50% grade could indicate competence is less than half of the learning outcomes. He believes that this is not an adequate license for professional practice. Johnstone's concerns are reflected in Bennett's findings, where in a review of examination papers he found that in some cases students were able to receive a pass grade with less than twenty percent of learning outcomes achieved. He also noted that questions that are easy to set and mark, tend to dominate examination papers and that the types of questions used do not necessarily test the claimed learning outcomes. In a recent paper, Bennett presented findings that showed that knowledge and comprehension questions are the predominant questions on first year chemistry examination papers with application, analysis, synthesis and evaluation questions following far behind. These findings are of concern especially when it is accepted that students focus their studying based on assessment expectations. If sections of courses are not assessed how can we be sure that students are proficient in these areas?

Yorke suggests that increasing amounts of summative assessment are being used within higher education and notes possible reasons for this:

- An increasing concern with attainment standards, leading to greater emphasis on the (summative) assessment of outcomes;
- Increasing student/staff ratios, leading to a decrease in the attention being given to individuals;
- Curriculum structure changing in the direction of greater unitisation, resulting in more frequent assessments of outcomes and less opportunity for formative feedback;
- The demands placed on academic staff in addition to teaching, which includes the need to be seen as 'research active', the generation of funding, public service, and intra-institutional administration.

To overcome these challenges of extra students, less time and structure pressures, researchers and practitioners are seeking to find new ways of delivering appropriate feedback. The Formative Assessment in Science (FAST) project was set up as a joint collaboration between the Open University and Sheffield Hallam University and also included approximately 20 other universities[119]. The project which involved over 30 different interventions finished in 2006. It used the Gibbs and Simpson framework for assessment mentioned previously (Table 1.5), and investigated a range of assessment changes at higher education with the aim of improving learning[120,121,122,123]. These focused on four overlapping areas; feedback, course structures, progress checks and the use of ICT. The projects have highlighted some key areas that have been addressed and have shown positive results. These relate to lecturer self-auditing in terms of feedback, in particular when and how it is delivered. It has been highlighted that much of the feedback that is given to students has little use and does not provide students with information to improve their learning. Some of the projects have highlighted the benefits of peer and self-assessment in that they allow increased feedback for students without the teacher having to supply it. This in itself has many benefits by reducing issues such as learned dependence and self helplessness, and increasing students' opportunities to develop self assessment skills necessary for independent learning. They have noted that this is a much under-used resource within the physical sciences. The projects have also shown positive results in terms of using ICT to provide assessment and valuable feedback that a lecturer could not possibly do with a large cohort of students. One such project was developed at the University of Bath for a first year chemistry module, and involved the introduction of answer specific feedback using the VLE, WEBCT which is now being modified for Moodle. The FAST projects are by no means the only research projects investigating ways of promoting formative assessment and a change in assessment methods in general; for example other authors have recently been advocating and showing positive results using peer assessment and computer aided assessment[115,124]. The FAST projects are mentioned as an indication of the present research being carried out on formative assessment, and the use of an effective framework, that will hopefully encourage and be transferred into practice across higher education.

1.3 Tackling Problems

Thus far, in this chapter an overview of how students learn, and factors influencing student learning have been presented. In chemistry, being able to solve problems is a key skill that students need to learn, particularly how to solve problems within the laboratory. In this section, problem solving will be discussed in relation to the previous discussion on student learning. Problem solving is identified as a higher order cognitive skill (HOCS) by Zoller, the development of which is a key aim of science education[125]. He notes that students need to develop problem solving skills to become responsible and effective citizens. "*Problem solving is a process in which various reasoning patterns are combined, refined, extended, and invented. It is much more than substituting numbers in well-known and practiced formulas; it deals with creativity, lateral thinking and formal knowledge*"[126]. Problem solving is often sighted in curricula both at second and third level as a key skill that needs to be developed[127,128,129]. It is referred to by employers as an important skill that they expect graduates to have[130,131]. As a result, there has been much recent research which has mainly focused on three issues; namely: (A) what is a problem? (B) what factors influence problem solving? and (C) can problem solving be taught? Each of these issues will now be discussed briefly.

(A) What is a problem?

There are many definitions of a problem. Hayes notes "*whenever there is a gap between where you are now and where you want to be and you don't know how to find a way to cross that gap, you have a problem*"[132]. Wheatley defines a problem as "what you do, when you don't know what to do"[133]. Problems have also been classified as closed or open-ended referring to the type of answer or methods required to solve the problems. Closed problems tend to be of the algorithmic type and have one answer, whereas open-ended problems could have numerous acceptable answers or, in cases where one answer is expected, there may be a variety of methods possible to reach that answer[134]. Probably one of the most useful descriptions of a problem is given by Johnstone[135]. He categorises problems into eight types which are determined by three factors; data, method and goal, i.e. data relates to the initial information provided in the problem, which can be either complete or incomplete; the method needed to be applied to solving the problem can be either familiar or unfamiliar, and the goal of the problem can be either clear or unclear (Table 1.7).

The categorisation in Table 1.7 is not a hierarchal system, although it is generally accepted that the Type 1 problem is not actually a problem but an algorithm or exercise to which the solution does not require problem solving skills. Solving exercises only require lower order cognitive skills (LOCS)[136] involving application of learned formulae and routine methods, thus students are not required to obtain or search for information, they do not have to develop strategies or use any judgement to reach a solution. Nakhleh noted that learning through and using algorithms does little to facilitate understanding of concepts and that Type 1 problems can be solved without the desired understanding[137]. She also proposes that emphasis on algorithmic exercises has a negative influence on students' interest in chemistry[138]. Interestingly and perhaps worryingly, Type 1 problems, algorithms and exercises, tend to be most common type of problems students encountered in school and university. This is supported by Bennett's study where it was found that in 82 examination papers from 32 universities across Australia, USA and the UK, 94.7% of the questions were of Type 1[139].

Table 1.7: Classification of different problem types adapted from Johnstone[135]

Type	Data	Method	Goal	Key Elements
1	Complete	Familiar	Clear	Recall of algorithm
2	Complete	Unfamiliar	Clear	Looking for parallels to known methods
3	Incomplete	Familiar	Clear	Analysis of problems to decide what further data is required
4	Complete	Familiar	Unclear	Weighing up possible methods and deciding on data required
5	Incomplete	Unfamiliar	Clear	Decision about appropriate goals; exploration of knowledge networks
6	Complete	Unfamiliar	Unclear	Decision about goals and choice of appropriate methods; exploration of knowledge and technique networks
7	Incomplete	Familiar	Unclear	Once goals have been specified by the student, they are seen to be incomplete
8	Incomplete	Unfamiliar	Unclear	Suggestions of goals and methods to solve the problem

The problems of Type 2-8 (Table 1.7) move away from the exercise style and into the realm of actual problems with Type 8 being most like a real-life problem. The Type 8 problem is very much ill defined and requires students to suggest goals, methods and add data[140]. Problem Types 2-8 require different strategies to solve the problem. These problems are much more challenging than the Type 1 style problems. They also expose students to the true nature of science and move away from the ‘only one right answer’ type questions where the students’ role is to clarify what the teacher already knows. Wood notes that this shift away is very important to our teaching, “*there is a danger of cultivating within our students an ‘all is known’ view of science: a discipline to which students can make no personal contribution*”[141]. Thus by participating in actual problem solving, students can be encouraged to see science as more of a creative subject that they can engage with, and develop a sense of responsibility and pride in their contributions.

What factors influence problem solving?

Both Reid and Gabel and Bunce identified the main factors that influence problem solving in terms of the problem, the learner and the environment[134,142]. The 'structure of the problem' plays an important role in successful problem solving including e.g. vocabulary used, presentation of information, and the number of variables involved. If sufficient care is not taken with these issues, it can unnecessarily raise the demand of a problem beyond a student's working memory capacity and indeed above that which was intended[143]. For example, if an ill-worded problem is given, a student may use valuable processing space trying to understand the terminology rather than trying to solve the desired problem. Students' individual characteristics, including previous experiences and cognitive factors such as working space capacity and field dependency are important in successful problem solving. Students' prior experience relates to what they know and how they learned it and this is not confined to school learning. It considers the learning experience, i.e. the learning processes as well as the learned content. As discussed previously, students' motivation and approach to learning can be influenced by previous learning experiences. A student who has had successful learning experiences will be more motivated and open to new learning and more likely to adopt a deep approach rather than a surface approach. This is the same for problem solving, (indeed many of the factors which influence learning also influence problem solving since it is a process of learning). A student who has had good experiences in problem solving will be more willing and motivated to solve future problems[144]. This is important as within problem solving, confidence is necessary as it encourages students to spend the required time analysing the problem; i.e. Reid notes "*the person may be willing to take cognitive risks, given a background of successful experience*"[145].

The information processing framework discussed previously can be applied to problem solving. How new concepts are linked to existing cognitive schemes in our LTM is very important to learning[146]. The value of linkages and organisation of knowledge is similarly significant for problem solving. De Jong and Ferguson-Hessler note that "good" novice problem solvers organise their knowledge differently to "poor" novice problem solvers[147]. In their study of problem solving in physics, they noted that "good" problem solvers tend to organise their knowledge in a more problem-type-centred way compared to "poor" problem solvers who sorted their knowledge based more on surface characteristics. This finding of different organisational strategies is supported in other studies[148,149]. In a study using open-ended chemistry problems with 2nd level students, Reid and Yang make the following 'tentative' conclusions based on their observations regarding LTM and problem solving.

- It is essential to have appropriate knowledge which must be linked correctly in long-term memory and be accessible;
- Knowledge seems to exist in long term memory as 'islands' and school pupils of this age (14-17) have great difficulty in forming links between the 'islands' unaided;
- When facing such open-ended problems, there is a strong unwillingness or inability to plan. These may be a feature of the lack of key links between 'islands' of knowledge. The pathways are not there and the pupil cannot see the logical steps towards solution.

The 'islands' of knowledge that Reid and Yang highlight, re-emphasise the importance of having a large body of appropriately linked knowledge. This perhaps suggests that problem solving is context based and may not be a transferrable skill. For example, a student may be good at problem solving in chemistry as they have developed appropriate linkages between their 'islands' of knowledge but the same student could be a poor problem solver in physics where, for whatever reason, they have not organised their learning in an effective manner. Other studies have found that having prerequisite knowledge does not automatically lead to successful problem solving[150,151]. Thus both students' previous learning experiences, and importantly their method of knowledge organisation and linking play a significant role in their problem solving abilities.

Tsaparlis has shown that working memory capacity and particularly field dependency are influential factors in successful problem solving in chemistry[152,153]. He notes that even though working memory capacity can be a good predictor for student performance, he observed that students can outperform or underperform compared to their capacity. Over performance can occur when the problem is not novel and the students have strategies to deal with the demand while students may underperform if they do not possess the strategies to deal with the demands of the problem. Field dependency factors have also been highlighted in other chemistry related studies[154,155]. These studies suggest that when considering these cognitive factors, students with high information processing capacities and who are field independent will be the best problem solvers. The use of representations in problem solving is another cognitive factor that can influence successful results. Bodner and Domin have shown that in general and organic chemistry, a difference between successful and unsuccessful problem solving is the students' ability to make representations of the problem[156]. Successful problem solvers tend to make both more and accurate representations which they can use to solve the problems. Bodner suggests that if students can be encouraged to move away from verbal/linguistic representations to visual representations, problem solving may be improved. Teaching of pictorial problem solving is also suggested by Waddling who indicates that the use of pictures helps students' comprehension as well as long term recall[157].

An important factor in teaching is to provide an environment that is conducive to learning. However, there is no 'one-fits-all' environment. An environment must be designed to suit both the particular learning task and the learners. The environment affects factors such as attitude, interest, motivation and achievement and encompasses many factors, both physical and social-psychological. The physical environment relates to the actual surroundings whether it is a classroom, lecture theatre or laboratory and how these are organised such as desk arrangements, tiered seating etc. The social psychological environment relates to classroom interactions, both student-teacher and student-student. It also relates to the instructional methods used by the teacher and the amount of order being placed on the environment. The instructional methods can be broadly considered as either formal or informal e.g. a class in which the teacher's main role is in giving direct instruction compared to a class where the students are free to walk about the class and the teacher's role involves observation and facilitation.

Group work, or more specifically cooperative learning has been advocated by researchers as a suitable environment for problem solving[126,134,145]. Cooperative learning is an extension of group work in which specific attention is paid to structuring the group and group interactions. "*A cooperative group has a sense of individual accountability that means that all students need to know the material for the whole group to be successful. Putting students into groups does not necessarily gain a cooperative relationship; it has to be structured and managed by the teacher or professional*"[158]. Johnson and Johnson's five elements of a cooperative group are summarised in Table 1.8:

Table 1.8: Elements of cooperative learning adapted from Johnson and Johnson[158]

Positive Interdependence	Each group's members' contribution is essential to reaching the end goal (Joint effort)
Face to face interaction	Individuals working together, encouraging and facilitating each others contribution to reach end goal (Vygotsky –ZPD)
Individual accountability/responsibility	Each member is accountable for contributing and being able to do all work related to the task (Done through assessment)
Interpersonal skills	Development of interpersonal skills: skills such as leadership and communication must be taught to the students and they must have an opportunity to practice them.
Group processing	Reflection on group goals and interactions in order to improve future collaborations

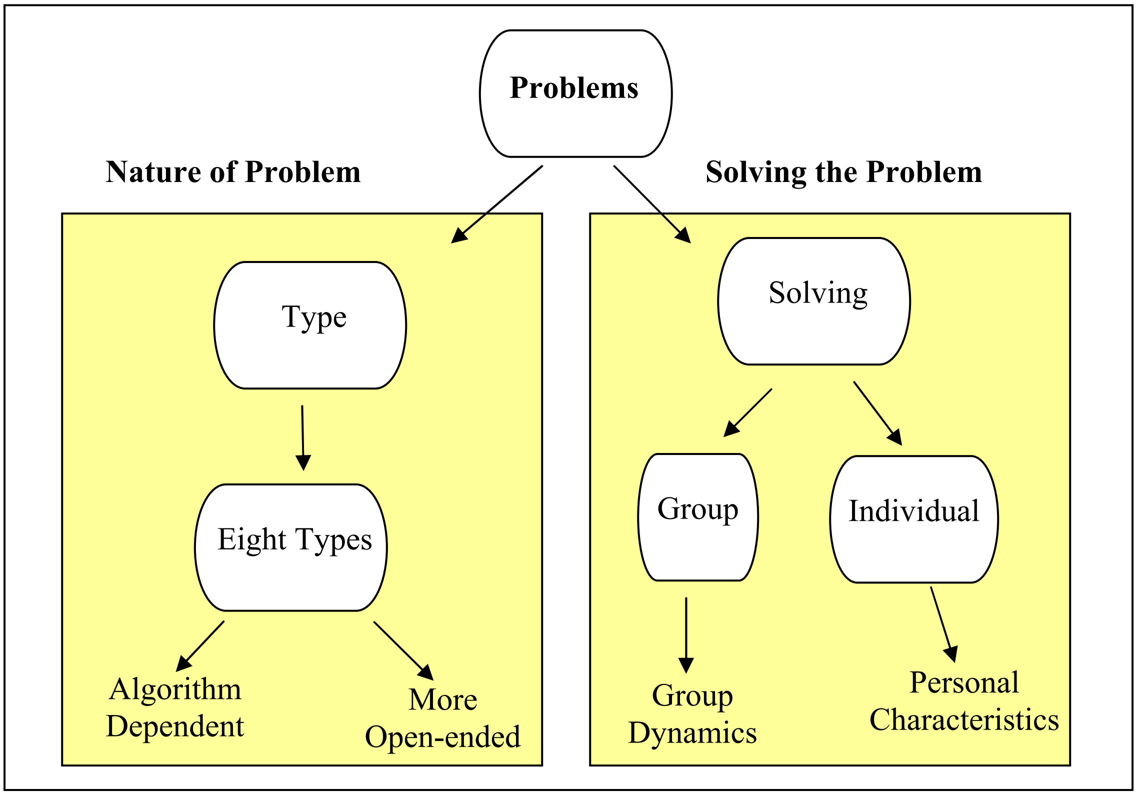
Qin *et al*[159] examined 46 studies published prior to 1993 relating to cooperative and competitive teaching of problem solving and concluded that cooperative environments promoted higher quality individual problem solving than competitive teaching. Cardellini notes benefits in problem solving when using group work. These benefits were observed in terms of better creative problem solving and motivation, though he did note that weaker students tended not to verify their solutions, perhaps indicating a break down in the group processing stage. Johnstone notes that group work would be beneficial in problem solving as students would have access to each others LTM and would also be able share out tasks over 'several working spaces'. In an analysis of problem solving approaches in order to devise appropriate assessments, Bennett notes that groups follow, and persist, with more unproductive leads than they do when working individually[160]. This situation perhaps emphases the importance of the role of the tutor in group work. Wood notes that "*there is a fine judgement need on the part of the teacher as to when to intervene and when to remain silent, when to encourage and when to act as a consultant*". In a review of teaching problem solving using cooperative learning, Gabel and Bunce, note mixed results regarding the benefits to students learning when comparing cooperative learning with individual learning. They suggest that learners' attributes (previous experience of group work, a group's conceptual base, student learning style and development level, and skill of the teacher in the role of group mentor) have significant influences on the effectiveness of cooperative learning. It would appear that there are benefits to using group work to teach students how to solve problems, however the teacher must be aware of group factors at play in order to achieve these benefits.

(C) Can problem solving be taught?

Problem solving is not a simple process. It involves skills that require insight and an ability to see things in new ways. A degree of creativity is needed to tackle these successfully[161]. In Figure 1.10, Reid highlights an overview of some factors that can influence problem solving. The numerous factors Reid identified perhaps indicate that there can be no 'quick fit-rules' developed to address all these situations. Indeed, Ausubel emphasises that no frequently practiced procedure or strategy could be called problem solving. There is a general consensus that Type 1 algorithms or exercises can be taught through routine and practice, and that it is "*possible to teach specific skills and routines which may be useful as a part of problem solving. The actual process of solving the problem is a much less accessible analysis*".

Many authors suggest that teaching instruction must be changed to teach towards problem solving[126,134,145,152,162,163,164]. Bennett notes that the advantages of teaching problem solving include greater student motivation, independence, reflection and retention. Phelps reports positive changes in interest and a move away from expectations of a single answer when a more conceptual problem solving teaching approach was made[165]. A summary of implications for teaching problem solving from the literature discussed is given below:

Figure 1.10: Overview of some factors that influence problem solving adapted from Reid



1. Be mindful of the cognitive capabilities of your students, introduce students to problem solving at a level that does not immediately overload a students working memory capacity.
2. Give students the opportunity to develop positive problem solving experiences; this will encourage them and give them confidence which is necessary for successful problem solving.
3. Teach material in an instructional manner that allows for and encourages students to develop links between compartmentalised knowledge. In some cases it may be necessary to be explicit about these links. (Be careful of how solutions to problems are presented to students in textbooks and in teaching, allow students the opportunity to see all steps in a solution to a problem even the mistakes)
4. Teach general strategies (including disembedding skills and making representations) to help students solve problems and give opportunities for students to reflect on their problem solving experiences to help them develop their own strategies.

5. Use group work /cooperative learning when problem solving.
6. Use/teach concept mapping skills, these can be beneficial in helping students identify knowledge in their LTM and also expand on this knowledge, creating more appropriate branches within their knowledge.

It must be noted that some authors question whether problem solving can be taught and if so, whether the skills are transferrable. Reid notes that within present research there is "*scant evidence that such skills can be transferred from one context to another*". Johnstone notes that it is possible to teach strategies that help the learner to narrow the gap but the last step is not teachable, "*we cannot teach insight which is the ultimate key to real problem solving*". However, though there are questions regarding the teaching and transferability, the authors still recommend teaching towards problem solving. "*Perhaps the best way forward is to offer our pupils increasing opportunities to face open-ended problems in chemistry, giving them the necessary support and encouragement so that they are able to develop their own strategies for success, based on growing confidence and experience which leads to a willingness in taking cognitive risks*".

In this chapter, an overview of student learning has been presented. Different perspectives on how students learn have been highlighted and a wide variety of factors that influence student learning have been discussed. Additionally an overview of 'problem solving' in the context of student learning has been given. It has been seen that student learning is extremely complex with many factors playing influential and interrelating roles. Learning is related to cognitive factors, motivation, student perceptions of learning, the teaching, the content, the environment just to mention a few. These overviews given serve as a framework for the analysis of student profiles and introduction of an undergraduate chemistry laboratory module used in this work. In Chapter 2 the methodology and results of the student profiles will be given and in Chapters 3 and 4 additional literatures, rationale and results of the laboratory implementation will be discussed. In Chapter 5, a conclusion on the findings of both the student profiles and laboratory implementation will be given.

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Chapter 2

Student profiles and engagement with teaching and learning supports

In Chapter 1, an overview of literature relating to student learning was given, identifying factors that affect student learning. Student interaction was one of the factors highlighted. Thus, a study monitoring students' interactions with learning supports was initiated. A 'virtual learning environment' (VLE) for a first year undergraduate organic chemistry module, and a 'Drop-in Science Clinic' (DISC) was piloted to determine if the availability of these supports actually increased students' engagement with their chemistry module. Following this initial study, which showed there was variation among students in terms of their engagement, a study to determine a 'student profile' of 1st year undergraduate chemistry students, with the aim of identifying factors within the profile, that could be correlated with academic performance was initiated. The 'student profile' investigated, was based on the 'learner considerations' noted in Figure 1, where a 'profile' includes students' motivations, preparedness for university, expectations of university, interaction with learning supports and approaches to learning at university. In Section 2.1, background information relating to the pilot study concerning student interaction with learning supports is given. In Sections 2.2 and 2.3, the methodology and research tools used to collect data relating to the pilot study and student profiles is presented and in Section 2.4, the results regarding students' interaction with learning supports and the generation of student profiles are given in five sections as outlined below:

- 2.4.1 Student engagement with learning supports
- 2.4.2 Student profile on entry to university
- 2.4.3 Student profile at the end of first year undergraduate study
- 2.4.4 Student profile at the end of second year undergraduate study
- 2.4.5 Correlations of student interaction with learning supports and student profiles with academic performance

2.1 Pilot Study Background – Student Interaction with learning supports

In Figure 1, it was noted that student interaction and engagement can influence the quality student learning. Fensham has noted that the physical sciences are facing problems of student disengagement[1]. He has discussed possible causes, such as a curricular focus on attainment of scientific knowledge, without attention to motivational aspects of science. He has noted the importance of scientific literacy and technology in encouraging an interest in science. Computers have been prevalent for many years in the physical sciences in that they are used in instrumentation and in data analysis within undergraduate programmes, and students have become adept in their usage. In Ireland, the higher education authority (HEA) has proposed the development of new ICT pedagogy for the improvement of teaching within higher education[2]. This reform has been stimulated by industry's call for a technically skilled workforce, and indeed, to address the needs of a changing society. There is a plethora of ICT resources and products available for use within the physical sciences. These resources include online lecture notes and tutorials, interactive software programmes, Virtual Learning Environments (e.g. webCT, blackboard, Moodle) and simulations. VLEs are in widespread use. In the UK, a *University Colleges and Information Systems Association* (UCISA) survey by Browne and Jenkins noted that 86% of their respondents are using a VLE in their institutes[3]. Recommendations on the implementation and evaluation of VLE have been discussed[4,5,6]. While anecdotal evidence seems to suggest that students like access to lecture notes and tutorial questions through VLEs, there has been little evaluation on the effectiveness of these supports in teaching and learning. Indeed, Rogers[7] noted that while there are gains in using learning technology, the claim that it can 'make the difference' to deeper learning requires much more research before further investment should be considered.

The VLE used in this study was *Moodle*. It is a web based Course Management System that allows the user to develop a VLE. It is open source software that can be freely downloaded from the web. There is an on-line Moodle community with over 200,000 registered users of the host site moodle.org. It is easily used and internationally accessible. It allows the educator to develop a course with multiple functions, including file hosting, quizzes, assignments, chats, discussion forums, glossaries and questionnaires. It is similar to the commercially produced VLE blackboard.com.

Student interaction and engagement may also be influenced by prior knowledge in the sense that, a student may become demotivated due to lack of basic knowledge that can often be assumed in a lecture course. To tackle this issue, a *Drop-in Science Clinic* (*DISC*) modelled on a Maths Learning Centre[8] was made available, where students could 'drop-in' at a time that suited them, to obtain help in any of the science subjects they were taking in their first year of undergraduate studies. In the pilot study it was attempted to determine if students interacted with the learning supports provided and if there were any correlations between student interaction and academic performance. The methodology and results of the pilot study are given in Sections 2.2 and 2.3, respectively.

2.2 Methodology

2.2.1 Sample Group

This study was carried out in Dublin City University (DCU). The university offers several undergraduate degree programmes in science including Biotechnology, Chemical and Pharmaceutical Science, Common Entry into Science, Environmental Science, Science International, Analytical Science, Genetics and Cell Biology and Science Education. There are approximately 200 students in total enrolled in these courses each year. These students take common first year chemistry modules (lectures and laboratories). The majority of students on these courses gain entry from points awarded for their performance in terminal post-primary examinations. There is also a requirement that students have obtained at least a C grade in one higher level science subject e.g. Physics, Chemistry, or Biology. A heterogeneous group of students is enrolled in the undergraduate chemistry modules in terms of previous chemistry experience, interest in chemistry, age, gender, programme choice and post-primary entry points.

Note: The abbreviations ‘PC’ and ‘NC’ will be used where PC refers to students with prior post-primary chemistry experience and NC refers to students without post-primary chemistry experience. These abbreviations will be used throughout this work.

2.2.2 Timeline and data collection

In this study students’ engagement with learning supports and student profiles in terms of motivation, preparedness, expectation and approaches to learning were monitored. The work in this study was carried out over a three year period. For the purposes of clarity, this study will be discussed in terms of ‘phases’ where each phase corresponds to a different cohort of students, i.e. phase 1 of this study refers to the cohort of students who started their university studies in the 2003-2004 academic year. In DCU an academic year is based on two 15 week semesters, consisting of 12 weeks of lectures, a two week study break and one week of exams.

In the first phase (pilot study) students' approaches to learning and students' engagement with learning supports, a VLE, Moodle and a DISC, was evaluated[9]. The VLE was made available for the organic section of the common first year chemistry lecture series. All students had previous experience of Moodle from their Biology studies. The material provided consisted of weekly self-test quizzes, lecture notes, tutorial questions, discussion forums and links to relevant sites. All of the material made available supported the content being presented in the organic chemistry lecture module. The self-test quizzes varied in difficulty so they would be accessible to PC and NC students. Discussion forums were made available so that students could ask each other chemistry related questions. This was an attempt to introduce an opportunity for students to engage in independent peer learning. The links provided directed students to websites that had explanations and visualisations of concepts being studied. Moodle logs were used to determine patterns of usage of each resource by the students. Student surveys and informal discussions with the students provided data on students' opinions of the resources provided. Students' approaches to learning were monitored as a continuation of a longitudinal study being carried out in DCU[10]. The data collection time, for the VLE introduction and the approaches to learning study is provided in Figure 2.1.

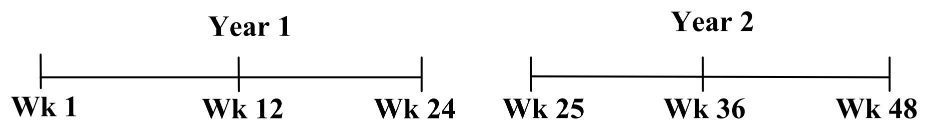
The DISC used in this study was made available to students during the second semester of their first year of university studies. It was open for 3 hours per week during the last 6 weeks of the second semester and then, 3 hours per day during the two week exam study break. The DISC was staffed by post-graduate students (tutors) in chemistry, physics and biology. Students were able to go to the clinic and ask questions relating to their course material. Students were expected to come with specific questions to the clinic, thereby encouraging them to go through their course work and seek answers to difficulties as they arose. The DISC had a very informal atmosphere, and if large numbers of students were present at the same time, group work and peer teaching was encouraged.

In phase 2 and phase 3, the study regarding students' approaches to learning was continued. In addition data regarding students' experience of and engagement with 1st

and 2nd year undergraduate chemistry was collected with the aim of generating a picture of student profiles as progress through their undergraduate studies. In Figure 2.1, an outline of data collected for this study is given. Data collected during each phase informed future work and it is noted that most complete data were obtained for phase 3. The development and background of each of the research tools identified in the Key of Figure 2.1 will be discussed in Section 2.3.

Data were collected during lecture and laboratory sessions. Surveys were completed voluntarily. Identifiers were included on all surveys for the purpose of matching students' responses. In cases where identifiers were not completed, that data were used where appropriate. Interviews were carried in small groups, with volunteer students, thus it cannot be assumed that they were representative of the entire cohorts; however some discussion of the interview data will be given in Section 2.4. In Table 2.1, the response rate for data collected is given.

Figure 2.1 Outline of data collection for all phases



Phase 1: A_1 V_1 A_2,V_2 A_3,

Phase 2: A_1 A_2, Ex_1, ExI_1 A_3,Ex_2, ExI_2

Phase 3: A_1, MPE, ExI_1 A_2, Ex_1, ExI_1 A_3, Ex_2, ExI_2

<u>KEY</u>

ASSIST Inventory = **A**
Motivation, Preparedness and Expectations = **MPE**
Experience = **Ex**
Experience Interviews = **ExI**
VLE = **V**

Table: 2.1 Sample responses for data collection (All phases)

Phase	Sample	N	Gender†		2nd Level Chemistry†	
			Male	Female	PC	NC
1	A_1	81§♠	38	43	47	28
	A_2	124♠	54	70	66	49
	A_3	48	20	28	35	10
	V_1	106	49	57	63	41
	V_2	94	47	47	57	36
2	A_1	175	82	93	-	-
	A_2	155	68	78	-	-
	A_3	58	19	37	-	-
	Ex_1	163	65	90	-	-
	Ex_2	54	14	38	-	-
	ExI_1	12	8	8	-	-
	ExI_2	13	8	5	-	-
3	A_1	164	70	64	76	81
	A_2	148	61	87	69	72
	A_3	29	10	18	22	4
	MPE_1	162	67	95	72	87
	Ex_1	139	55	84	66	67
	Ex_2	71	28	42	41	20
	ExI_1	10	7	3	6	4
	ExI_2	10	6	4	6	4

§Inventory was collected digitally
♠Inventory was collected in conjunction with previous DCU study[10]
†Not all students completed all identifiers thus information could not be determined

2.2.3 Data Analysis

Detailed descriptions of research tools are detailed in Section 2.3. All data obtained were analysed using Statistics Package for Social Sciences (SPSS) for Windows versions 14 and 15. Within the questionnaires developed, a variety of questions types were used where responses were either qualitative or on Likert scales[11].

Criticisms within the literature regarding the use and analysis of Likert scales relate to (a) apparent confusion between the terminology of *Likert items* (the question) and *Likert scale*s (summation of the Likert items); (b) the number of Likert points used and how people respond to these, (c) the validity of analysing Likert items, (d) whether the data produced from a Likert item/scale is interval or ordinal and (e) whether parametric (e.g. *t*-tests) or non-parametric (e.g. Mann-Whitney U tests/Wilcoxon signed-ranks test) statistical analysis should be used to analyse Likert items and scales[12]. If Likert scales are considered to be ordinal then the intervals on the scale cannot be deemed to be equal[13,14,15], this would imply that only non-parametric analysis could be used; thus any numerical operations analysis such as mean and correlations would not be valid and that mode and medians should be used instead. However, the uses of non-parametric tests for Likert scales also been criticised[16,17].

In practice, a wide variety of analysis techniques have been used for Likert scale analysis. Clason and Dormody reviewed 188 research articles published in Agriculture Education and observed a multitude of different analysis being used[12]. Similar findings have been reported by Blaikie and Jamieson[18,19]. In this work, after consideration of the research literature above and following discussion with a statistician, it was decided that, based on the questions being asked and the sample sizes involved, it was appropriate to use parametric tests for the analysis. Likert scales were checked for internal reliability using the Cronbach's alpha test and summed subscales were checked for normality using Q-Q plots. Additionally, several spot checks were made in which non-parametric analyses were also carried out and the resulting findings were compared with those from the parametric analyses. In all cases, comparable findings were observed. The specific statistical analyses used on the various research tools will be further discussed in Section 2.3

Data presentation

Paired and independent *t*-tests were used to monitor changes in students' motivations, expectations and preparedness for university. Similarly, *t*-tests were used to monitor change in students' approaches to learning in line with the methods used in the previous DCU study[10]. Values of p less than 0.01 indicate a 99% significant finding and p values less than 0.05 indicate a 95% significant finding. Pearson correlations were used to investigate the relationship between student profile and academic performance. In all tables an asterisk (*) is used to indicate a significant finding. In Tables presenting findings from *t*-tests, the sign of the *t*-value indicates the relationship of the test items e.g. if a deep approach is compared to a strategic approach and a significant difference is observed, the *t*-value is positive and the mean value of the deep approach is greater. If the *t*-value was negative it would indicate that the mean value of the strategic approach is greater. Similarly, positive and negative signage is also used in relation to Pearson Correlations indicating the relationship between test items.

Mean values are only given as a general indicator of trend changes between years; it is not given as an indicator of significant differences in students' responses. It is acknowledged that the mean can be misleading e.g., a mean of 3 could be observed if there was an equal distribution of responses to each option on the Likert item, similarly a mean of 3 could be observed if half of the responses were strongly agree and the other half strongly disagree. Thus, throughout this text, the mean is also accompanied by the percentage responses given by students to give a better indication of the spread of students' responses. For ease of presentation some of the percentages are grouped e.g. the responses to strongly agree and agree are grouped together, however none of the Likert scale data is grouped for the purpose of data analysis.

2.3 Research tools

In this section, detailed information regarding the research tools used in this part of the study will be provided. Where relevant, the development, structure and validation of the tools used will be discussed.

2.3.1 Student engagement with learning supports

In Sections 2.1 and 2.2 it was discussed that phase 1 students' engagement with two learning supports were monitored. As highlighted in Figure 2.1, students completed two VLE surveys, one prior, and one at the end of the Moodle supported organic chemistry module (Copy of surveys given in the Appendix). The surveys inquired about students' engagement with lectures, tutorials, ICT access and ability and study patterns. They also asked about students' opinions of and engagement with Moodle. Additionally, students' patterns of access to the resources made available on the Moodle site were monitored by examination of the Moodle log hits. The log hits provided detailed information of students' interaction with the Moodle, where each time a student accessed a resource a corresponding log hit was recorded. These log hits were collated for each student in order to generate a pattern of student usage.

The evaluation of the DISC was based on attendance records, subject areas requested and feedback from the tutors involved. The results relating to students' engagement with the two learning supports will be given in Section 2.4.1.

2.3.2 Motivation

The Motivation, Preparedness and Expectation for Undergraduate Chemistry (MPE) Survey was used to determine (a) the main factors that influence students to attend university (b) students' expectations and intentions towards university life and study and (c) how prepared students feel for study at university (Copy of survey given in the Appendix). The development of this survey was based on two surveys used in other studies[20,21]. The first survey was that from Byrne *et al,* who investigated university business students' motives, expectations and preparedness for university[20]. This survey was actually carried out in DCU. The second survey was the Academic Motivational Scale (AMS) developed by Vallerand *et al* which investigated students' reasons for attending university[21]. In this Section, questions from the MPE survey relating to students' motivation for coming to university will be discussed. The preparedness and expectation components will be discussed in Section 2.3.3.

Four questions from the MPE survey are related to students' motivations for attending university. The first three questions inquired whether students were enrolled on their first preference course, whether they had enjoyed chemistry at second level and what influenced them to attend university. The fourth questions contained 13 statements relating to motivations for attending university; students were asked to indicate their level of agreement to these statements on a Likert scale. The statements used in this question are shown into Table 2.2. These questions were categorised in-line with the AMS categorisations, into three types of motivation; intrinsic, extrinsic and amotivation. Further categorisation based on the self-determination discussed in Section 1.2.1 was not possible due to the number of questions asked.

The internal reliability of the fourth motivation question was evaluated using the Cronbach's alpha test for internal reliability, where "reliability is defined as the ability of a measuring instrument to measure the concept in a consistent manner"[25]. Cronbach's alpha measures inter-item correlations and alpha values above '0.7' indicate good reliability[22]. The Cronbach's alpha value for the motivation question was 0.732 signifying good reliability.

Table 2.2: Motivation Questions used in determination of students reasons for attending University

Categorisation of statements used to monitor students motivation for entry to university		
a	I want to develop knowledge and skills I can use in a career	Ex
b	I hope the things I learn will help me to develop as a person and broaden my horizons	In
c	I'm focused on the opportunities here for an active social life and/or sport	-
d	I hope the whole experience here will make me more independent and self-confident	In
e	Having done well in school, going to university was the natural thing to do	Am
f	Coming to university affords me three more years to decide what I really want to do	Ex / Am
g	I want to study the subject in depth by taking interesting and stimulating courses	In
h	All my friends were going to university	Am
i	I want an opportunity to prove to myself or to other people what I can do	Ex
j	Progression to university is what others expected of me	Ex
k	I mainly need the qualification to enable me to get a good job when I finish	Ex
l	I want to learn things which might let me help people, and/or make a difference in the world	In
m	When I look back, I sometimes wonder why I ever decided to come here	Am

In = Intrinsic Motivation, Ex = Extrinsic Motivation, Am = Amotive Motivation

In Chapter 1 it was discussed that students' motivation for learning is one element (the intention) of an approach to learning and it was noted how some theories of motivation could be linked to approaches to learning e.g. goal theory and approaches to learning. It was decided to correlate phase 3 students' approaches to learning with their initial motivation for coming to university as a tentative method to validate the motivation statements. Phase 3 students were chosen as they were the only group to complete the MPE survey as highlighted in Figure 2.1. To do this, three groupings of the motivation statements in terms of extrinsic, intrinsic and amotive motivation were made (Table 2.3). The reason for the three groupings was the uncertainty of which type of motivation statement 'f' belonged, i.e. was it extrinsic or amotive. Statement 'c' was not used in any of the groupings as there was complete uncertainty to where it could be included e.g. it could be intrinsic for students who want to do sports but extrinsic towards academic studies. For the purpose of analysis the response for each of three groupings were summed, standardised and correlated with the ASSIST approaches to learning (Table 2.4 and Section 2.3.5). The intrinsic motivation statements positively correlated with a deep approach ($p = 0.008$) and both the extrinsic ($p = 0.000$) and amotivation ($p = 0.000$) statements positively correlated with a surface approach (Table 2.4). None of the motivations correlated with a strategic approach which is not surprising since only a few of the statements in any of the groupings related to a strategic approach. The results from the correlations, though tentative, do at least justify the distinction of the intrinsic motivations from the extrinsic and amotive groupings.

Table 2.3: Grouping of motivation statements

	Grouping 1 (*f as extrinsic*)	Grouping 2 (*f excluded*)	Grouping 3 (*f as amotive*)
Extrinsic	a,i,k,j,f	a,i,k,j,	a,i,k,j,
Intrinsic	b,d,g,l	b,d,g,l	b,d,g,l
Amotive	m,e,h	m,e,h	m,e,h,f

2.3.3 Expectations and preparedness for university

The second part of the MPE survey as mentioned, relates to students' expectations and preparedness for university. This component was also developed from the survey used by Byrne *et al*[20]. The expectation questions inquire about students' intentions towards study e.g. the number of hours they intend to study, whether they are going to have a part-time job, the grade they are aiming to achieve and the topics they hope to cover. The preparedness question consists of 14 statements to which students indicate their response on a Likert scale. These statements relate to students' confidence in terms of study skills, willingness to participate and engage with colleagues and teaching staff and ability to work independently. As noted in Figure 2.1, only phase 3 students completed this survey. Cronbach's alpha test was also used to check the preparedness question for reliability. A Cronbach's alpha value 0.817 was recorded indicating good reliability for the question used.

Table 2.4 Pearson correlation of motivation statements with students' approaches to learning (phase 3)

Motivation	**Category**		**Deep**	**Strategic**	**Surface**
Intrinsic	1,2,3	Pearson	**0.277****	0.158	0.041
		Sig	0.008	0.063	0.632
		N	137	140	138
Extrinsic	1	Pearson	-0.029	0.158	**0.336****
		Sig	0.732	0.063	0.000
		N	138	140	138
Extrinsic	2,3	Pearson	-0.006	-0.060	**0.309****
		Sig	0.941	0.484	0.000
		N	138	140	138
Amotive	1,2	Pearson	-0.078	-0.060	**0.296****
		Sig	0.364	0.484	0.000
		N	137	140	138
Amotive	3	Pearson	-0.077	-0.060	**0.312****
		Sig	0.374	0.484	0.000
		N	137	140	138

** Correlation is significant to the 0.01 level (2-tailed)

2.3.4: Experience in University

As outlined in Figure 2.1, phase 2 and phase 3 students completed surveys relating to their experience in university. The experience surveys sought to investigate four key questions:

1. Are students' motivations for attending university realised?
2. Are students prepared for university?
3. Do students' expectations of university match their experience?
4. Do students' engage with teaching and learning environments and what were there opinions of these?

There were some variations in the experience surveys used in each phase of this study though the majority used related to these four key questions. Additional questions were added to phase 3 surveys based on analysis of phase 2 responses. The experience surveys completed at the end of year one and year two for each phase contained many identical questions. These are used in the analysis to monitor changes in student experience. Copies of the experience surveys can be found in the Appendix.

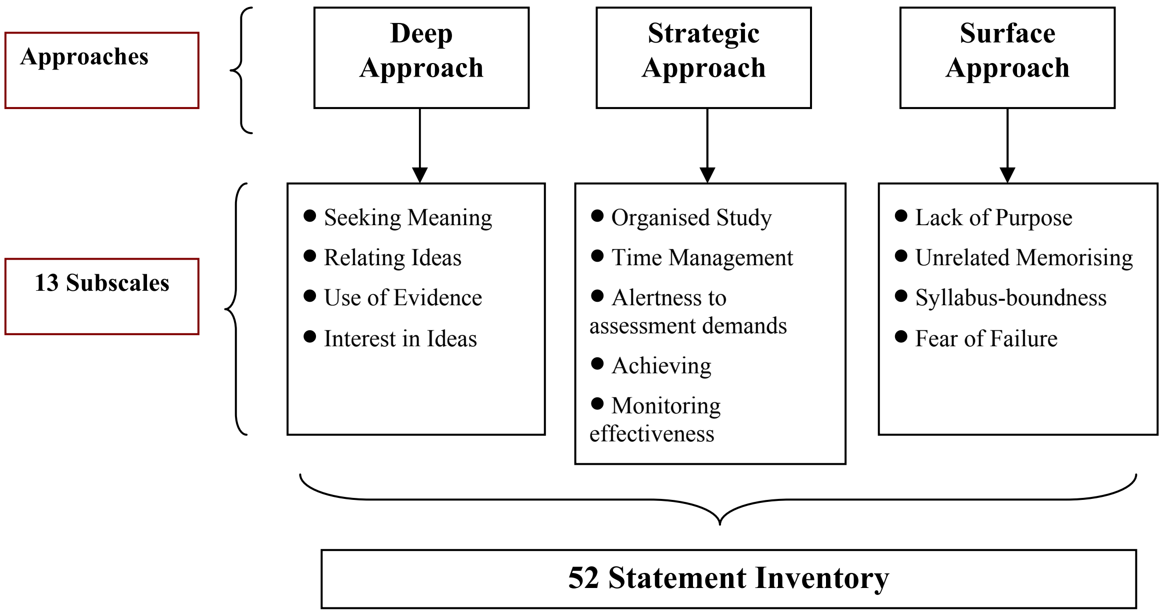
2.3.5 Approach to Learning

As discussed previously, this study on students' approaches to learning forms part of a longitudinal study where the profile of the change in student characteristics can be monitored. In the previous DCU study, the ASSIST Inventory was chosen to determine students' approaches to learning[10]. In this Section, background information and validation data relating to the use of the inventory will be given.

The ASSIST Inventory

The ASSIST inventory is a 52 statement inventory (Copy given in the Appendix). Students indicate their level of agreement to each statement on a 1-5 point Likert scale. The statements relate to 13 subscales each of which relate to the different approaches to learning; deep, strategic and surface (Figure 2.2).

Figure 2.2: Outline of ASSIST inventory, adapted from Entwistle 2000[23]



From Figure 2.2, it is seen that deep and surface approaches have four related subscales and the strategic approach has five related subscales. Each subscale thus has four related statements on the inventory. In the analysis, all of the subscales are summed together and their scores are standardised out of 20 before statistical tests are carried out, e.g. to determine the value for a deep approach, students' responses for seeking meaning, relating ideas, use of evidence and interest in ideas would be summed together. To determine the validity of using the inventory, factor analysis and internal reliability checks were carried out.

The guidelines set out by the previous DCU study and ETL to measure the construct validity of the ASSIST inventory were followed[10,24]. In the previous studies 'factor analysis' was used to confirm whether the 52 statements on the inventory related to the three approaches to learning suggested. Factor analysis is a data reducing statistical test that examines relationships between scores on different items (in this case, the 52 statements) and determines whether there are underlying factors that explain correlations between the items[25]. Before factor analysis is used two tests, Kaiser-Meyer-Olkin (KMO) and Bartlett's Test of Sphericity are run to ensure factor analysis is viable. The KMO test measures 'sampling adequacy' to check whether the data can be used for factor analysis. KMO values above 0.5 justify the use of factor analysis[22]. The Bartlett's Test of Sphericity determines whether there are correlations between the items on the inventory. When this test is significant it indicates that factor analysis can be used.

KMO and Bartlett's Test of Sphericity were performed on the data in this study. All KMO values obtained were above the 0.5 cut off point and Bartlett's Test of Sphericity was significant for all data analysed. 'Principle factor analysis' was the factor analysis test used in this study. The results of this were comparable to the previous DCU study and the ETL project[10,24]. In Table 2.5, the factor analysis for phase 3 of this study is shown. The table presents the rotated eigenvalues which correlate to the factors extracted. The closer the values are to '1' the higher correlation they have to the extracted factor. Values below '0.3' have been removed as these values, below this point, do not contribute to the factors extracted[25]. From Table 2.5, it is noted that three factors are extracted by the factor analysis. In column three it is seen that four subscales are related to the third factor extracted. These subscales correspond to a surface approach. Similarly, it is observed that in column one the majority of subscales highlighted relating to the factor extracted refer to a strategic approach and the subscales highlighted in column two relate to a deep approach. There are overlaps of some of the subscales observed, for example 'seeking meaning' and 'use of evidence' appear to contribute to a deep approach as well as a strategic approach and 'monitoring effectiveness' seems to also overlap between a deep and strategic approach. Monitoring effectiveness has been noted to overlap with a deep approach in all of the DCU studies except a pilot cohort noted by Kelly[10]. Indeed in the ETL scoring system, it is identified as a related sub-scale as similar overlapping was noted in that study[24]. The overlapping of the 'seeking meaning' subscale between both a deep and strategic approach is noted for phase 3 of this study but not for phase 1 or phase 2 of this study, although it has been noted in all of the other previous DCU studies. In line with the previous studies, it has been decided to disregard the overlapping subscales in the statistical analysis and keep the original structure of the ASSIST inventory. This is done as it is observed that the Eigenvalues for the overlapping subscales are considerably lower than the values obtained for the expected subscales.

Table 2.5: Rotated eigenvalues from factor analysis of ASSIST Inventory (phase 3)

Subscales	**Factors**		
	1	**2**	**3**
	(Strategic)	(Deep)	(Surface)
Seeking meaning	0.355	0.677	
Relating ideas		0.802	
Use of evidence	0.305	0.744	
Interest in ideas		0.502	
Organised study	0.785		
Time management	0.777		
Alertness to assessment	0.551		
Achieving	0.556		
Monitoring effectiveness	0.591	0.466	
Lack of purpose			0.649
Unrelated memorising			0.831
Syllabus-boundness			0.591
Fear of failure			0.675

Reliability checks for internal consistency were also carried out. Cronbach's alpha values were obtained for each approach and for all of the individual subscales. In Table 2.6 the Cronbach's alpha values for all phases of this study are compared with the previous DCU studies and that of the ETL project. All values except for the phase 2 surface approach were above '0.7' indicating good internal consistency[25]. Although, most of the Cronbach's alpha values obtained for the subscales in this study were not above '0.7', they are comparable with other studies using the ASSIST inventory[10,24,26,27]. Since the values recorded are comparable with these studies and the main approaches scales are above '0.7', it is deemed suitable to use the inventory in this research.

Table 2.6: Comparison of Cronbach's alpha values for approaches to learning

Scale	ETL[24]	DCU[10] 02-03	DCU[10] 03-04	DCU[10♠] Phase 1	DCU Phase 2	DCU Phase 3
Deep	0.84	0.81	0.82	0.84	0.77	0.81
Strategic	0.80	0.80	0.83	0.87	0.82	0.86
Surface	0.87	0.74	0.74	0.77	0.64	0.78
Subscales						
Seeking Meaning	0.57	0.59	0.59	0.63	0.53	0.56
Relating Ideas	0.59	0.53	0.57	0.58	0.55	0.61
Use of evidence	0.53	0.49	0.54	0.70	0.55	0.60
Interest in ideas	0.76	0.63	0.72	0.76	0.63	0.57
Organised studying	0.54	0.58	0.57	0.59	0.51	0.64
Time management	0.68	0.70	0.74	0.74	0.55	0.77
Alertness to assessment demands	0.62	0.57	0.60	0.59	0.49	0.65
Achieving	0.76	0.67	0.63	0.72	0.55	0.56
Monitoring effectiveness	0.62	0.61	0.56	0.63	0.50	0.67
Lack of purpose	0.76	0.73	0.71	0.80	0.67	0.75
Unrelated memorising	0.57	0.56	0.60	0.66	0.61	0.58
Syllabus-boundness	0.55	0.58	0.61	0.65	0.52	0.48
Fear of failure	0.69	0.74	0.75	0.77	0.68	0.74

♠Phase one was carried out in collaboration with previous DCU study[10]

As mentioned in Section 2.2.3, paired and independent *t*-tests were used to analyse the ASSIST data. For the *t*-test analysis of the inventory, three assumptions are made, (1) the sample is normally distributed, (2) the data is from an interval or ratio scale and (3) the data comes from populations with equal variances[25]. In line with the previous DCU study, Normal and Detrended Normal Q-Q (Quartile-Quartile) probability plots were obtained to check that the sampling data were normally distributed. If these plots show data which is clustered about a straight line then that data is said to be normally distributed[28]. Figures, 2.3 and 2.4, show the Q-Q plots for the deep approach for phase 3 of this study. Both plots are consistent with data that is normally distributed. It is observed that some outliers are present in the plots. This was also the situation in the previous DCU study, thus it was deemed acceptable to assume the data is normally distributed (assumption one). Q-Q plots obtained for all three phases of this study for each of the approaches satisfied the assumption for normal distribution. The other two assumptions for *t*-tests analysis are met as a likert scale is used (assumption two) and SPSS automatically carries out a Levene's Test for equal variance (assumption three).

Figure 2.3 Q-Q plot for deep approach (Phase 3)

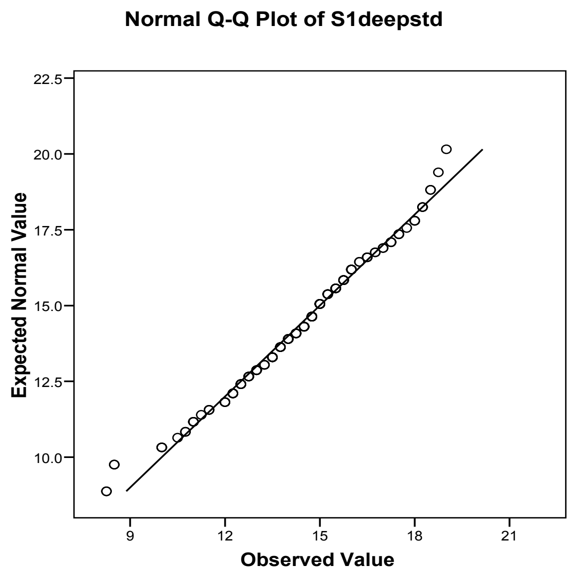
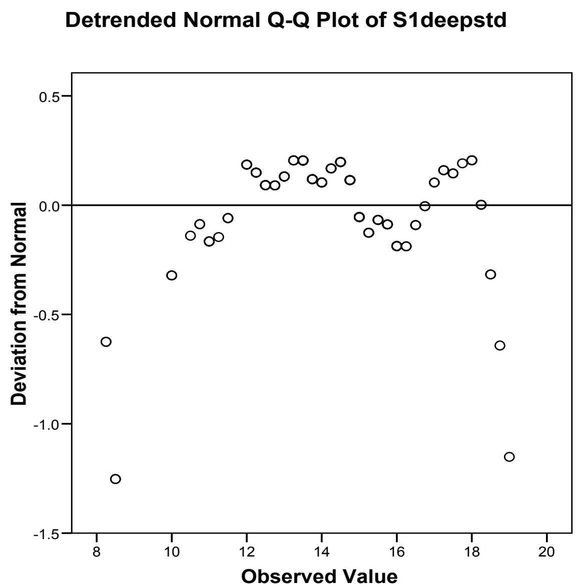


Figure 2.4: Detrended normal Q-Q plot for deep approach (Phase 3)



Results obtained and discussion

In Sections 2.2 and 2.3 the methodology and research tools used to investigate and monitor students' engagement with learning supports and student profiles (students' motivations, expectations, and preparedness for university, students' approaches to learning and students') have been discussed. In this Section results relating to the analysis of the data obtained are presented. The findings will be discussed in five sections.

2.4.1 Student engagement with learning supports
2.4.2 Student profile on entry to university
2.4.3 Student profile at the end of first year undergraduate study
2.4.4 Student profile at the end of year second year undergraduate study
2.4.5 Correlations of students' interaction with learning supports and student profiles with academic performance

As mentioned previously, most data were generated in relation to phase 3 of this study. With the exception of the 'evaluation of students' engagement with learning supports', the results will be discussed primarily in relation to phase 3 of this study. Where possible these results will be compared to the first and second phases of this study, however phase 1 data relating to students' approaches to learning will not be given since this has been previously published[10].

2.4.1 Student engagement with learning supports

As stated in Section 2.1, a VLE learning support was provided for the organic chemistry component of the first year undergraduate chemistry lectures and a DISC was made available during the last 6 weeks of the second semester of students' first year undergraduate studies. In this section the findings regarding students' engagement with the learning supports will be discussed.

Student VLE engagement

Moodle logs indicated that there were 12,179 student log hits on the site associated with 187 Moodle users out of the 199 students registered for the module. Student responses to the VLE survey highlight that the majority of surveyed students who accessed the

Moodle support did so at least once over the duration of the module; 2% accessed Moodle several times a day, 27% of the users accessed Moodle once a day, 59% accessed the module once a week, and 12% accessed Moodle once a month/seldom. Two of the students surveyed had not used Moodle for the module. One claimed to be too busy with other modules to use it and the other did not give a reason. Student access varied between college hours (52%), in the evening (40%) and at the weekend (8%), with the majority of access occurring on campus (77%). Students identified key features of Moodle that they liked; namely being able to access lecture notes outside of lecture time (32%), having after out-of-college-hours access (25%), off-campus access (24%), and instant feedback from the quizzes (19%). An indication of overall usage was obtained from the Moodle log hits (see Table 2.7). The number of hits is given to demonstrate the general level of interaction students had with each Moodle resource. Though, further analysis of the individual hits is required to determine the actual activity with respect to numbers of students. Weekly quizzes had the most hits, followed by lecture notes and tutorial questions. However, lecture notes were the most accessed resource, based on the number of individual students who accessed the resources, followed by quizzes and then tutorial questions.

Table 2.7: Total resource hits from Moodle logs

Resources	No. of Students	Hits
Lecture notes	177	2993
Quizzes	147	3353
Tutorial Q's	137	868
Web links	♠	533
Forums & Disc.	♠	578

♠Specific student numbers for these were not analysed using Moodle logs as the numbers involved were very small.

A breakdown of student hits per resource during the 6-week organic course is given in Table 2.8. It is clear that resource usage generally decreased as the module continued. This is especially evident in relation to quiz access, where for quiz 1 (week 1), there were 1608 hits and for quiz 4b (in week 6) only 154. Interestingly, the tutorial question access was greatest for tutorial 5 in which both questions and solutions to all previous tutorials were provided. Note: there were six quizzes used on the site, these were made available to students corresponding to the delivery of the related content in the lecture series. Quizzes that have ‘a’ and ‘b’ in there titles had similar content but varied in their level of difficulty.

Table 2.8: Moodle usage illustrating hit per resource used throughout the module

Resource	Week 1	Week 2	Week 3	Week 4	Week 5	Week 6
Lecture Notes	590	482	582	556	425	358
Quizzes	1608	604	400	371	219	154
Web-links	178	96	101	82	76	-
Tutorial Questions	208	164	147	120	229	-
Discussion Forums	293	-	139	-	146	-

Specific patterns of student access to lecture notes and quizzes were determined from Moodle logs. Detailed access patterns to web-links, tutorial questions and discussion forums were not analysed. Figures 2.5 - 2.7 show access patterns for lectures notes and quizzes. The ‘weeks’ indicated in the Figures refer to the implementation period of the organic chemistry component where weeks 1-6 correspond to the weeks of organic chemistry lectures, weeks 7-8 correspond to study break and week 9 was the exam week.

Figure 2.5 identifies a two-peak general trend in student access to lecture notes. Firstly, there is a peak in access corresponding to the week of the lecture when the notes became available. Access generally drops off quickly after this. However, lecture note access rises again at week 6 up to week 9. The average number of accesses per student was 1.9. Overall, the number of hits per lecture note is on average 1.6 times greater than the number of students accessing the notes. This indicates that students do not necessarily download the lecture notes when they access the resource, as some are accessing it repeatedly. Figure 2.6 shows the number of students who are accessing lecture notes for the first time in the respective weeks of the module. It is evident that the majority of first access takes place in the week the resource was made available, however, there are still students accessing the notes in the study and exams weeks for the first time.

Figure 2.5: Number of students accessessing lecture notes

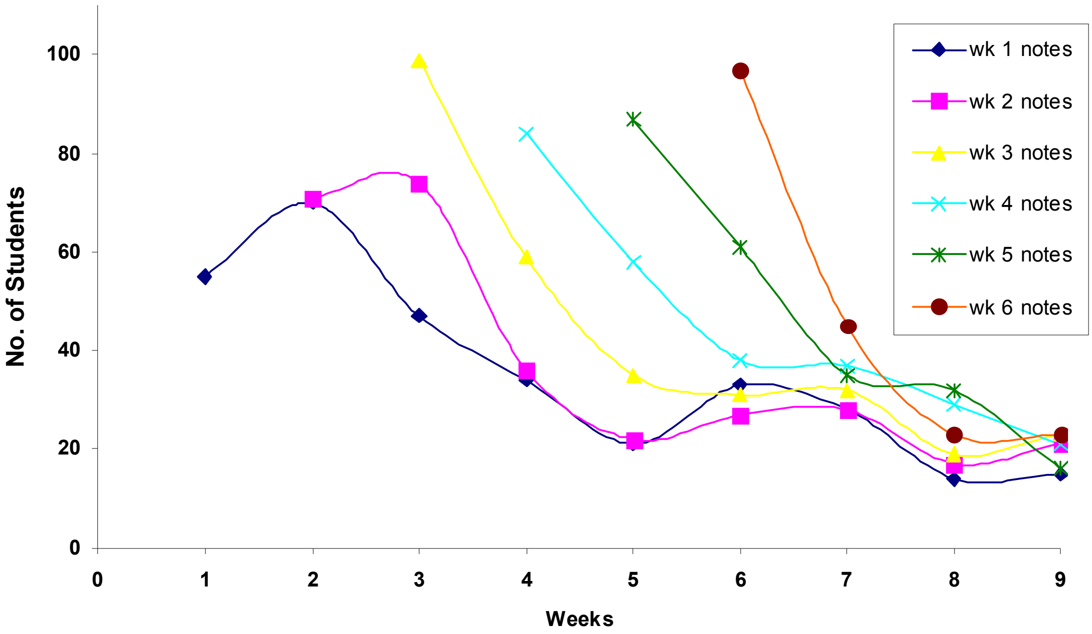
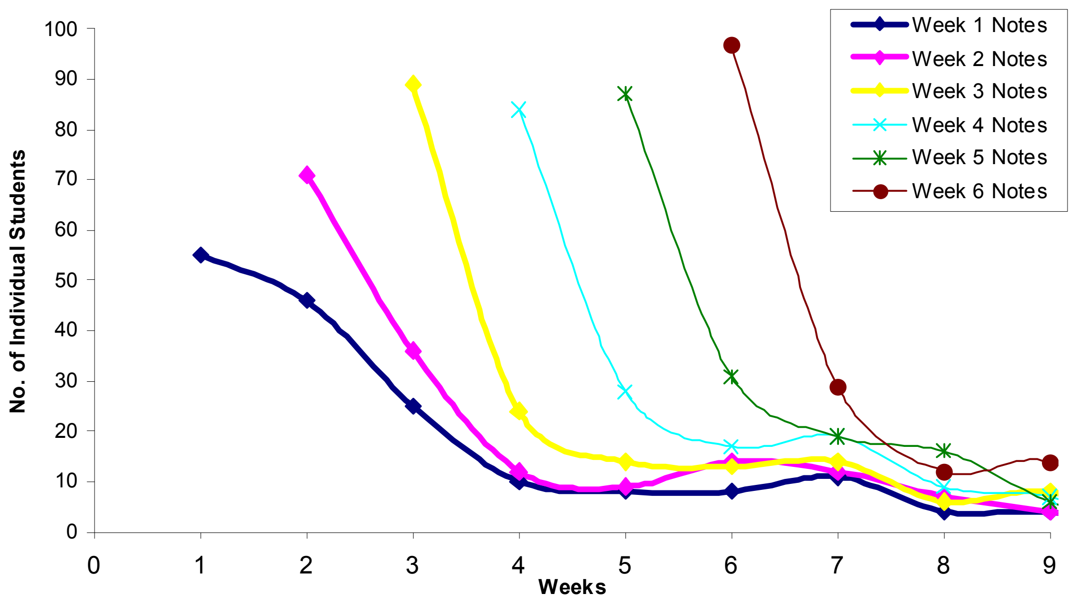


Figure 2.6: Number of students' first access to lecture notes



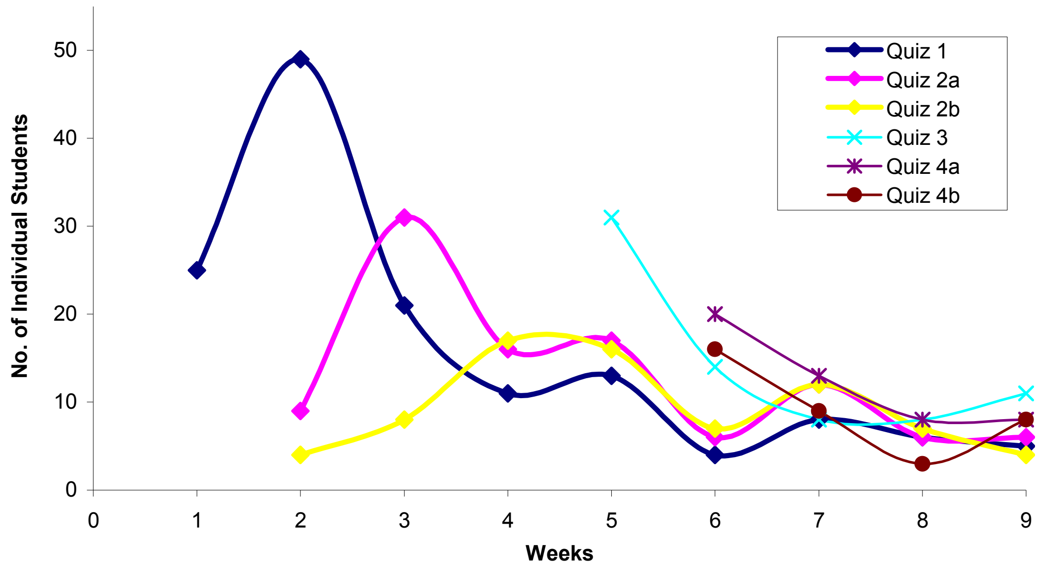
From these Figures, it is clear that more than half of the students used the on-line support to access the lectures notes during the lecture period, but there were significant numbers of students accessing these resources for the first time at exam time. Quizzes were made available to students on Moodle in weeks one, two, five and six of the module. The pattern of quiz access is shown in Table 2.9. Quiz usage substantially decreased during the module. Students only received solutions to the quizzes if they submitted their answers. From Table 2.9 it is clear that many of those who accessed the quizzes did not submit them; this may imply that the students found the quizzes either too easy or too difficult. The fact that the quiz usage decreased during the module could possibly support the latter explanation.

Table 2.9: Quiz usage (number of students)

Quiz	Accessed	Submitted	% Accessed	% Submitted
Quiz 1 (Week 1)	140	91	70.3	45.7
Quiz 2a (Week 2)	99	52	49.8	26.1
Quiz 2b (Week 2)	71	38	35.7	19.1
Quiz 3 (Week 5)	68	31	34.2	15.6
Quiz 4a (Week 6)	49	25	24.6	12.6
Quiz 4b (Week 6)	35	16	17.6	8.0

Figure 2.7 identifies the pattern of first access to each quiz. Quizzes were not used very much during the exam study weeks. However, a two peak trend, similar to that highlighted in relation to lecture note access was observed. The first peak corresponds to the week the resource was made available, and the second during the study and examination weeks. It is clear that the first peak in this trend decreases for the later quizzes, pointing towards a waning interaction with the quizzes in the later weeks of the module. The findings from this analysis points towards decreasing engagement with the VLE support as the module progressed. It also highlights that some students are only accessing resources at the time of examinations perhaps indicated that they do not engage during the module. These findings as mentioned previously were part of the impetus to further investigate student profiles in undergraduate chemistry. In the next Section, student profiles at the beginning of their university experience are discussed.

Fig 2.7: Number of students' first access to quizzes



Student DISC engagement

The DISC was available to the first year students during the last 6 weeks of their second semester and for the 2 week study break before the examination. Only eighteen students attended during the semester, averaging 2 visits per student (actual number of visits varied from 1 to 4). During the study break 32% of the first year students attended. Interestingly these students were from all levels in the class – first class honours students as well as those who had failed first semester examinations. Only 26% of the attendees had failed the first semester examination. Therefore, it had a broad range of appeal. While 17% of the students who visited the clinics did so on at least 5 occasions during the study break, and many stayed for several hours, 37% visited only once. These students, who only visited once, arrived with specific problems and generally left confident that they had resolved their issues. The areas where student questions arose were 61% chemistry, 28% physics and 11% biology.

It is difficult to measure the effect of the clinic on examination performance. However, feedback from the students was favourable in that the students who attended them liked them. From the learner's perspective, the question arises as to whether such initiatives encourage students to engage only at exam time. Students' questions asked at the DISC were generally focussed on specific past examination paper questions. This in itself may not be unusual before an examination; however, it was noted by the tutors that it was evident that the students' focus was on obtaining the answer rather than on obtaining any detailed explanation/background to the chemistry involved. Of the students who attended the DISC, 27% had not attempted the quizzes that were available on Moodle. Some students had a selfish approach, displaying a 'help is available – its all for me' attitude. It was not uncommon during the study break for students to enter the DISC with all of their notes and ask the tutor to tell them what sections were needed to pass the exams.

Conclusion

In conclusion students' engagement with two learning supports has been monitored in phase 1 (pilot study) of this work. Students generally liked the Moodle support. They identified 'ease of use' and 'accessibility' as positive aspects of the support. Their preference for each resource was reflected in their usage. Lecture notes, quizzes and tutorials were predominately used and students requested more solutions to be available on the support, including past exam papers, worked tutorial questions, quizzes and assignments. However, usage of the support generally decreased as the module progressed. There was a two peak trend observed in student access to the resources. The first peak occurred in the week the resource was made available and the 2nd peak related to the examination study period. This 2nd peak of access includes both students who are accessing the resource for the first time and repeat users. It was noted that there was a number of students who accessed lecture notes for the first time in the exam week. For the most part, it is noted that the level of access to resources decreased as the module progressed, this was particularly evident for the quizzes. The experience of the DISC supports the belief that students do wish to succeed in the examinations but also highlights the fact that significant numbers of students only access course material for the first time only during exam weeks as noted in relation to the VLE. It is apparent that we must use learning supports in a way that is much more beneficial and encouraging to the student in order to promote more independent learners. One of the challenges in science education noted previously was an increased disengagement with science. The finding from the pilot study appears to support this issue and implies that students need to be encouraged to engage with their course material earlier and consistently. The finding also highlights differences in students' engagement patterns, and raises the question, why do some students engage and others do not? This finding was the impetus for the work carried out in phase 2 and phase 3 in which student profiles were investigated and a new laboratory module was introduced to encourage student learning and engagement.

2.4.2 Student profile on entry to university

The MPE survey was used to measure students' motivation for attending university as discussed in Section 2.3. 'Interest in subject' was noted as the primary influence by the majority (62%) of students for attending DCU, followed by 'career' (22%). In Section 2.3.2 a categorisation (intrinsic, extrinsic and amotivation) of the primary motivation question was given. In Table 2.10, student responses to these statements are presented. Students indicated their highest overall level of agreement was towards the 'intrinsic' motivation statements. They appeared to be focused on learning that would help them to become more independent (88%), develop as a person (83%), allow them to make a difference in the world (77%) and they wanted to study interesting and stimulating content (74%). Student response to the categorised 'extrinsic' statement, 'I want to develop knowledge and skills I can use in a career' received the highest individual agreement (99%). Interestingly, only 77% of students agreed to the statement 'I mainly need the qualification to get a job'. It appears that, though a job was important to students, their attendance at university was heavily influenced by learning knowledge and skills. There were lesser levels of agreement observed to the other 'extrinsic' statements, highlighting that peer or family pressure was not a major influence on students' attendance at university. Student responses indicated very low levels of agreement to the 'amotive' categories, with the exception of the statement, 'having done well in school, going to university was the natural thing to do'. 76% of students agreed with this statement compared to an average of 15% agreement to the other two 'amotive' statements. Finally, only 34% agreed to the statement 'coming to university affords me three more years to decide what I really want to do' perhaps indicating that students were fairly clear on the career they wished to pursue. The findings are consistent when gender background is investigated, however there were some differences observed based on students prior chemistry experience. NC students appeared less motivated by 'studying the subject in depth and taking interesting and stimulating courses', (p = 0.010). They also indicated a higher agreement to two of the amotive categorised statements; 'when I look back I sometimes wonder why I ever decided to come here' (p = 0.014) and 'all of my friends were going to university' (p = 0.012). However, it should be noted that, while there were significant differences between PC and NC students observed in relation to these statements, amotivation still had least influence on students' reasoning for attending university.

Table 2.10 Student motivation for attending university, % agreement with each statement (Phase 3)

	N	Strongly agree / agree	Somewhat /not sure	Very weakly /weakly agree	Mean
I want to develop **knowledge and skills** I can use in a **career**	160	99	1		4.8
I hope the things I learn will help me to **develop as a person** and **broaden my horizons**.	160	83	15	2	4.3
I'm focused on the opportunities here for an **active social life and/or sport.**	158	68	24	8	4.0
I hope the whole experience here will make me **more independent and self-confident.**	160	88	10	2	4.4
Having done well in school, going to university **was the natural thing to do.**	159	76	14	10	4.1
Coming to university affords me **three more years to decide what I really want to do.**	160	34	28	38	3.0
I want to **study the subject in depth** by taking **interesting and stimulating** courses.	158	74	23	3	4.1
All **my friends were going to university.**	160	22	15	63	2.3
I want an **opportunity to prove** to myself or to other people **what I can do.**	159	57	23	20	3.6
Progression to university is what others **expected of me.**	159	54	14	32	3.3
I mainly **need the qualification** to enable me **to get a good job** when I finish.	160	73	18	9	4.0
I want to learn things which might **let me help people, and/or make a difference in the world.**	159	77	18	5	4.1
When I look back, **I sometimes wonder why I ever decided to come here.**	159	7	11	82	1.6

In Table 2.11, students' responses regarding their perceived preparedness for university are given. Table 2.11, also divides the responses into five loose groupings namely, learning responsibilities, willingness to engage (ENG), study skills (SS), ICT preparedness (ICT) and academic expectations (AE). Students generally indicated high levels of agreement to the statements relating to these groupings. They appeared willing to engage with their courses. 90% of students were willing to participate in class, 77% were willing to engage with lectures and students (89%) were comfortable when working in groups. Similarly, students were equally confident in their ICT abilities. However, there does appear to be a general lack of confidence in planning and making oral presentations. There are some seemingly conflicting responses regarding the 'learning responsibilities' statements. Students (80%) believed they were able to take responsibility for their learning and indeed 77% feel they could organise their own lives generally; however, they were less confident regarding their ability to work without teacher direction (48%), ability to plan their study and meet deadlines (56%) and to evaluate their own progress (59%). These learning responsibilities are key skills which are required for university study and highlight an area that needs to be addressed during the initial stages of university programmes. Students' prior chemistry experiences appeared to have no influence on students' perception of preparedness for university study, however it is observed that female students rated themselves better able to organise their own lives (p = 0.041) but less confident in planning and making oral presentations (p = 0.001) than their male colleagues.

Students' expectations of university were also investigated using the MPE survey. In Table 2.11, it is shown that 64% of students believed they knew what was expected of them academically at university and 88% of students noted that they are aiming to achieve a high honours grade, though 45% indicated they would be happy with a low honours or pass mark. It is also noted that NC students were aiming for (p = 0.024) and would be happier with (p = 0.001) a lower grade in chemistry than PC students (p = 0.024). Student responses highlight that in addition to their required contact hours, students intended to study up to 11 hours each week, with four of these hours been directed towards chemistry. The majority of students (80%) also expected to have a part time job, working an average of 13 hours each week.

Table 2.11: Students' preparedness for university study, % agreement with each statement (Phase 3)

Statement	N	Strongly agree / agree	Somewhat /not sure	Very weakly /weakly agree	Mean	Group
I know what is **expected of me academically** in university	158	64	28	8	3.8	AE
I am able to **work independently without** much **direction from a teacher**	158	48	41	11	3.5	LR
I am able **to initiate my own study** activities	155	68	26	6	3.8	LR
I am able to **plan my study** in a **time effective manner** to **meet** all my **deadlines**	157	56	31	13	3.6	LR
I am able to **take responsibility for** my own **learning**	158	80	18	2	4.0	LR
I am able to **evaluate** my own **progress**	157	59	36	5	3.8	LR
I am able to **organise my own life** generally	155	77	21	2	4.0	LR
I am **comfortable** working **in groups**	156	89	10	1	4.4	ENG
I am willing to **participate in class**	157	90	9	1	4.4	ENG
I am willing **to ask for help** from my lectures/tutors	156	77	19	4	4.1	ENG
I am confident in planning and making **oral presentations**	157	32	36	32	3.0	SS
I am confident about my ability to complete **written assignments**	157	74	23	3	4.0	SS
I am confident about my ability to **use a computer**	156	72	19	9	4.1	ICT
I can **use internet** and other resources to gain information	157	89	10	1	4.5	ICT

AE = Academic expectation, LR = Learning responsibility, ENG = willingness to engage, SS = Study Skills, ICT = ICT preparedness

As discussed in the introduction to this work (Figure 1), the approach students adopt to their learning influences the quality of the learning outcome achieved. Student responses to the ASSIST inventory on entry to university highlighted that they adopt more deep and strategic approaches to learning compared to a surface approach (Table 2.12). However, there are no significant differences observed between their preference between deep and strategic approaches at the start of their university studies.

Table 2.12: Students' approaches to learning at entry to university

Year	Paired-Approach	Diff	σ	t	df	p
Phase 3	Deep-Strategic	0.13	2.06	0.79	147	0.428
	Deep-Surface	2.14	3.31	7.85	146	0.000*
	Strategic-Surface	1.94	3.41	6.99	150	0.000*
Phase 2	Deep-Strategic	-0.08	2.59	-0.35	144	0.725
	Deep-Surface	2.46	3.80	7.78	144	0.000*
	Strategic-Surface	2.58	3.48	8.91	144	0.000*

From Table 2.12 it is evident that this trend is followed for phase 2 of this study. Indeed the same trend was found in the previous DCU study[10]. Since the ASSIST data were collected during the initial stages of university study it is suggested that these findings represent students' approaches based on their previous learning experiences and their expectations for study at university. The 13 subscales which contribute to the overall approaches were also investigated in relation to students' approaches to learning as they start university (Table 2.13). It is observed that certain subscales are consistently scored higher than others. In terms of a deep approach, students rated 'use of evidence' the highest and 'interest in ideas' the lowest. In the strategic approach subscales, 'monitoring effectiveness' were scored high whilst 'organised studying' was rated particularly low followed closely by 'time management'. Students rated the surface subscale 'fear of failure' particularly high (mean = 14.3), though they rated 'lack of purpose' quite low, indeed it was the lowest scored subscale. These findings were comparable with the findings of phase 2 of this study and the previous DCU findings[10]. The data were further analysed in terms of gender and students' previous chemistry experience. Gender differences were not significant in relation to students' overall approaches to learning. However, some differences were observed when the subscales were investigated. Female students consistently scored higher on 'organised study' (p = 0.030) and 'fear of failure' (p = 0.002). This would perhaps indicate that they are better at organising themselves in relating to their study and that a fear of failure is a more dominant motive for their study compared to their male colleagues. NC students scored the surface approach significantly higher than PC students (p = 0.002). The subscales 'lack of purpose' (p = 0.006), 'unrelated memorising' (p = 0.000) and 'syllabus-boundness' (p = 0.045) were all rated higher by NC students. However, they still indicated a higher preference for deep and strategic approaches over a surface approach.

Table 2.13: Average score for each ASSIST subscale

Approach	Subscales	Phase 3	Phase 2
		Mean	Mean
Deep	Seeking meaning	14.2	14.4
	Relating ideas	14.1	14.3
	Use of evidence	15.0	14.6
	Interest in ideas	13.9	13.6
Strategic	Organised study	12.7	13.4
	Time management	13.1	13.8
	Alertness to assessment demands	14.8	14.5
	Achieving	14.8	14.8
	Monitoring effectiveness	15.6	14.9
Surface	Lack of purpose	8.7	9.3
	Unrelated memorising	12.6	12.3
	Syllabus-boundness	13.3	12.3
	Fear of failure	14.3	13.1

'Interest in subject' and 'future career' have been observed as the two most prominent factors that influenced students to start university. Students appeared to be intrinsically motivated to attend university and they highlight a want to 'develop knowledge and skills', and to take 'interesting and stimulating courses'. They also indicated a greater preference for deep and strategic approaches to learning compared to a surface approach. For the most part, students perceived themselves to be well prepared for university study especially in terms of their ICT skills and indicated a willingness to participate and engage with teaching staff. However, they appeared to be less confident in terms of being independent learners i.e. they were unsure of their ability to initiate their own studies, organise their study to meet deadlines and work without direction from a teacher. These findings highlight a difficulty which students have and it is suggested that this should be addressed early in their undergraduate studies. This will be discussed later.

2.4.3 Student profile at the end of first year of undergraduate study

In Figure 2.1 it was highlighted that students completed an experience survey (Ex_1) at the end of their first year of undergraduate study. Their response to the Ex_1 survey was used to investigate whether students' actual experience of first year matched their initial motivations, expectations and preparedness for university study. In this Section the findings from the Ex_1 survey, including students' engagement with their chemistry modules, will be discussed. In addition students repeat responses to the ASSIST Inventory will also be presented, to determine if their approach to learning had changed during the first year.

It is first noted that 92% of students were happy to attend university and 82% of students surveyed indicated that they were happy to attend DCU. In Table 2.14, students' repeat responses to the 'motivation' statements at the end of their first year are given. Students (80%) indicated that they have developed knowledge and skills which they could use in a career and they (76%) felt that they have learned things to help them personally develop and 81% point towards becoming more independent and self-confident. However, only 42% of students believed they had 'studied chemistry in depth by taking interesting and stimulating courses' and 49% of students didn't believe that what they have learned would allow them to make a difference in the world. Although students are mostly positive regarding the statements given Table 2.14, their responses to each of the statements at the end of the year were significantly lower than what they had indicated on the MPE survey at the start of their studies. In relation to these motivation questions, there were no difference observed at the end of the year when prior chemistry experience was considered, though it was observed that female students agreed significantly less to the statement 'I have studied chemistry in depth by taking interesting and stimulating courses' ($p = 0.045$).

Table 2.14: Comparison of students' initial motivations for attending university and their first year experience (phase 3)

Statement	Strongly Agree / agree	MPE	EX_1	Diff	*t*	*df*	*p*
I have developed **knowledge and skills** that I can use in a **career.**	80%	4.74	4.07	-0.67	8.55	123	0.000*
I have learned things that will help me to **develop as a person** and **broaden my horizons.**	76%	4.29	3.95	-0.34	3.70	123	0.000*
I have an **active social life** and/or sport in DCU	66%	3.93	3.65	-0.28	2.43	122	0.016*
My 1st year experience has made me **more independent and self-confident.**	81%	4.41	4.04	-0.37	3.75	123	0.000*
I have studied chemistry in depth by taking **interesting and stimulating courses.**	42%	4.10	3.18	-0.92	9.24	120	0.000*
I have learned things that might let me **help people**, and/or **make a difference in the world.**	49%	4.12	3.31	-0.81	7.03	120	0.000*

MPE: Motivation, preparedness and expectations survey completed on entry to university
Ex_1: Experience Survey completed at the end of year 1
Diff: Mean difference between responses given on the MPE survey and EX_1 Survey

In Table 2.15, students' repeat responses in relation to their perceived preparedness for university are given. There are no changes in students' confidence towards ICT. At the end of the year, 80% of students were confident they could use computers and 97% pointed out that they were able to use the internet to gain information. There are also no changes observed in relation to students' study skills, i.e. confidence in writing assignments (80%) or making oral presentations (52%). There do however, appear to be some mismatches in students' initial perception of their 'willingness to engage' and their 'learning responsibility' preparedness to that expressed at the beginning of their studies. Only 53% of students felt that they are able to ask their lecturer questions about content they didn't understand and only 48% have asked when they needed help. This represents a significant drop compared to students' initial responses on the MPE survey. In relation to the 'learning responsibility' grouping of statements, 70% of students believed they have taken responsibility for their learning, 69% of students noted that they have worked independently and 59% felt they had organised their own life during the first year of their studies. However, somewhat contradictorily and perhaps worryingly, only 38% of students had evaluated their own progress and were able to plan their study to meet deadlines. Student responses to the 'learning responsibility' statements were all significantly lower to that indicated when they started university. Similarly to the motivation questions, prior chemistry experience had no influence on student responses to these statements, however differences with respect to gender were observed. Female students felt less confident in their ICT usage ($p = 0.011$), less able to ask their lecturers questions ($p = 0.004$) and less confident in making oral presentations ($p = 0.005$).

The 'Ex_1' survey was also used to compare students' initial expectations of their course and intentions to study with their experience at the end of their first year of study. Overall, 61% of students indicated that their course matched their initial expectations, though 39% did not concur. Few students gave reasons for their incorrect expectations, but those that did pointed towards not being fully aware of the course structure and/or content. One student stated, 'there is much more chemistry and physics than I expected' and another wrote 'I didn't realise I would be doing labs for all three subjects'.

There were changes observed regarding students intentions towards study. Phase 3 students (70%) noted that they studied an average of five hours each week and 95% pointed out that they spent two hours each week studying chemistry. This is an approximate 50% drop from their initial intentions. In Table 2.16 the grade in chemistry that students were aiming for and would be happy with are highlighted. 54% of students were aiming for a high honours grade however, 70% of students noted that they would be happy with a pass grade. This represents a significant ($p = 0.000$) drop in expectation in both of these cases compared to the MPE responses. It was also observed that NC students aimed for lower grades ($p = 0.000$) and were satisfied with lower grades ($p = 0.000$) than PC students. Students' intentions towards achieving high grades are

Table 2.15: Comparison of students initial their perceptions of preparedness (MPE) for university and their first year experience (EX_1) (phase 3)

Statement	Agree	MPE	EX_1	Diff	*t*	*df*	*p*
I know what is expected of me academically in university	71%	3.85	3.83	-0.02	0.26	121	0.794
I have worked independently without much direction from a teacher	69%	3.57	3.71	0.14	1.46	121	0.147
I have initiated my own study activities	58%	3.85	3.55	-0.30	3.16	118	0.002*
I am able to plan my study in a time effective manner to meet all my deadlines	38%	3.55	3.09	-0.46	4.30	120	0.000*
I have taken responsibility for my own learning	70%	4.09	3.83	-0.26	3.07	119	0.003*
I have asked for help from my lecturers/tutors when needed	48%	4.13	3.33	-0.80	6.81	119	0.000*
I am confident about my ability to use a computer	80%	4.19	4.08	-0.11	1.38	119	0.169
I am comfortable when working in groups	76%	4.45	4.00	-0.45	5.00	120	0.000*
I am comfortable about my ability to complete written assignments	80%	4.06	4.10	0.04	0.53	120	0.594
I feel able to ask my lecturer questions about material I don't understand	53%	4.48	3.52	-0.96	9.80	121	0.000*
I have evaluated my own progress	38%	3.83	3.20	-0.63	6.47	121	0.000*
I have organised my own life generally	59%	4.10	3.60	-0.50	5.54	120	0.000*
I am confident in planning and making oral presentations	52%	3.08	3.25	-0.17	1.80	121	0.075
I can use internet and other resources to gain information	97%	4.50	4.59	0.09	1.35	121	0.180

MPE: Motivation, preparedness and expectations survey completed on entry to university
Ex_1: Experience Survey completed at the end of year 1
Diff: Mean difference between responses given on the MPE survey and EX_1 Survey

further investigated. Only 51% of students indicated that they wanted to achieve high grades in every year of their study and 38% were only concerned in gaining marks in the years that count towards their final degree. In the phase 2 study the data follows a similar general trend.

Table 2.16: Percentage number of students expected chemistry grades (phase 2 and 3)

Grade	Grade aimed for / expected		Grade satisfied with	
	Phase 3 (aimed)	Phase 2(expected)	Phase 3	Phase 2
H.1	25	9	10	11
H.2.1	29	4	20	7
H.2.2	25	28	30	21
Pass	21	59	40	61

When asked about the amount of effort they committed, 76% of phase 3 students indicated that they thought they had committed enough effort to pass chemistry and only 35% felt they had committed enough effort to achieve high marks in chemistry. Few students indicated reasons for the lack of effort applied to achieve high grades. The responses of those that did fell under three categories namely; ‘not being motivated enough’, ‘found it difficult’ and ‘time constraints’. Since the response rate to this question was quite low, it is not possible to suggest that these reasons are representative of the entire cohort. These findings were comparable to the phase 2 study in which 71% and 32% of students indicated that they committed enough effort to pass and achieve grades in chemistry respectively.

In the ‘Ex_1’ survey students were also asked to indicate their level of attendance at lectures and tutorials and also gave their opinions of these learning environments. In Figures 2.8 and 2.9, students’ indication of their level of attendance at chemistry lectures and tutorials are shown. It is observed that students’ lecture and tutorial attendance for their chemistry modules decreased in the second semester. The percentage of students who attended between 75-100% of lectures dropped from 67% to 40% and from 80% to 71% for tutorials from semester 1 to semester 2. It is also evident that students appeared to attend more lectures than tutorials. For phase 2 of the study, it is noted that students attended less lectures and tutorials in the second semester. However students attended more lectures than tutorials unlike the phase 3 students.

Figure 2.8: Student attendance at lectures and tutorials (Phase 3)

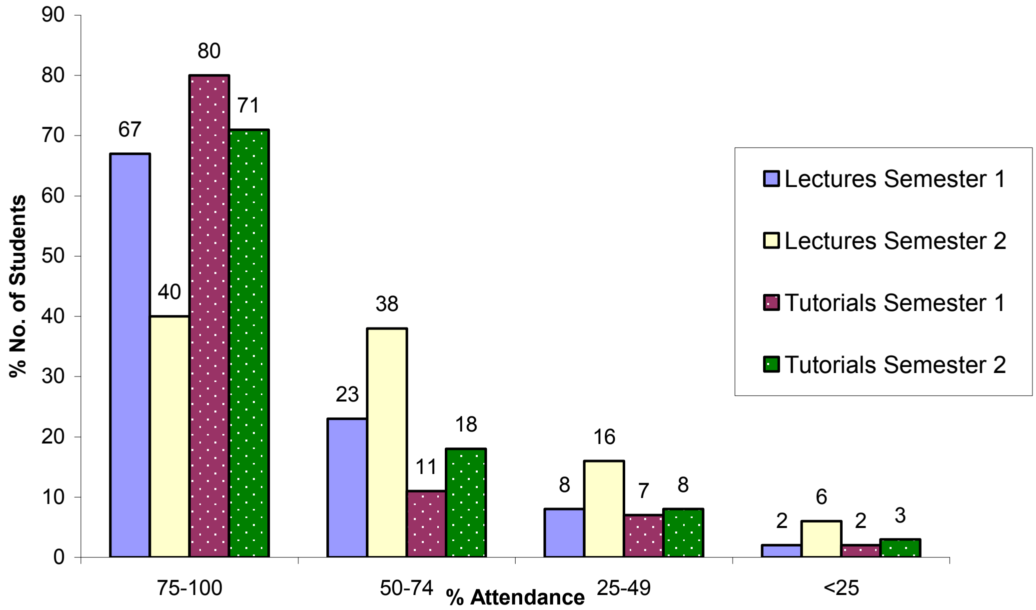
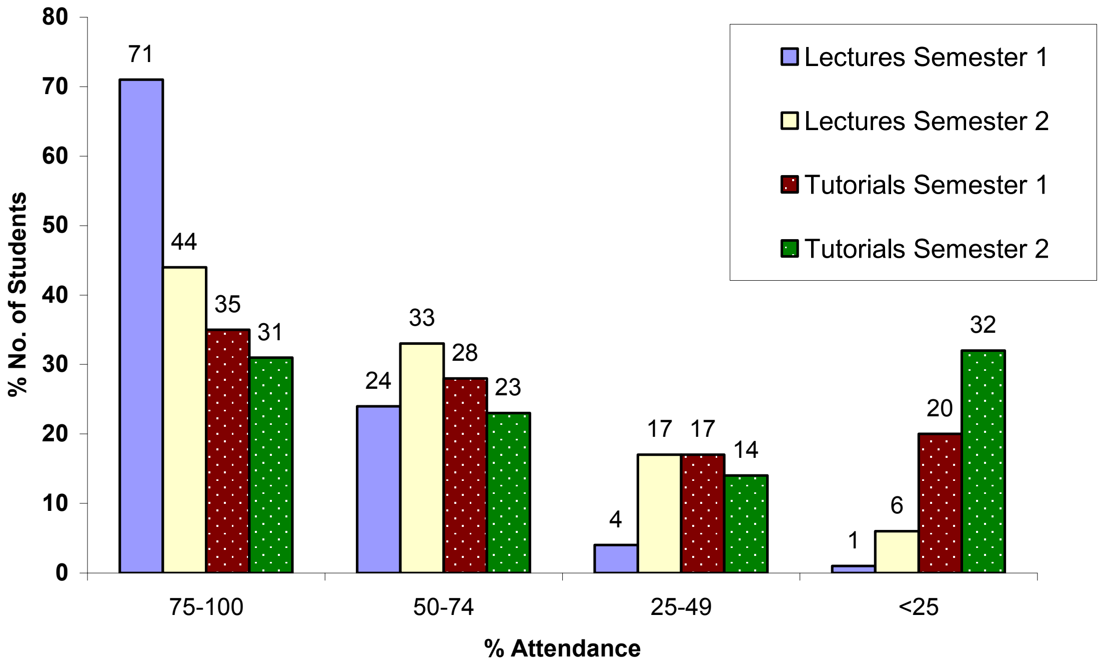


Figure 2.9: Student attendance at lectures and tutorials (Phase 2)



In Table 2.17, students' opinions of lectures and tutorials are given. It is evident that the students surveyed liked both lectures and tutorials. Interestingly they noted that they liked second semester lectures and tutorials slightly more even though they attended less of them. Students were equally positive regarding the learning gained from attending lectures and tutorials. Approximately 77% of students felt they learned from lectures and 85% of students believed they learned from tutorials. Students also indicated that lecture attendance (~80%) and tutorial attendance (~88%) related to examination performance. It is observed that students felt they learned more from tutorials and felt that attendance at tutorials was more related to examination performance. This appears to correlate with students' greater attendance at tutorials than lectures. Phase 2 students also indicated that they liked lectures more than tutorials. This finding reflected their attendance patterns. It also reflects their view that they felt they learned more from lectures than tutorials.

Table 2.17: Student opinions of first year lectures and tutorials

% Number of Students		Liked♠		Learned from♦		Related to exam performance†	
		P3	P2	P3	P2	P3	P2
Semester One	Lectures	79	82	78	80	77	79
	Tutorials	69	56	84	70	87	78
Semester Two	Lectures	84	76	77	79	82	78
	Tutorials	77	61	86	66	89	83

P3= Phase 3 of the study
P2 = Phase 2 of the study
♠ Did you like the chemistry lectures / tutorials you attended?
♦ Did you feel you learned from the chemistry lectures / tutorials you attended?
† Do you think chemistry lecture/tutorial attendance is related to good performance in chemistry exams?

Although students indicated they liked lectures, they didn't appear to find them interesting (Table 2.18). Only 47% of students pointed towards finding lectures interesting, though it is certainly clear that they believed the content covered in lectures was important for performance in examinations. 92% of students noted that they think they would have to show an understanding of lecture content in examinations and 47% indicated that they would have to show in examinations that they studied outside of what was covered in lectures. This may explain the finding that 32% of students were motivated to read around their lecture material. Interestingly, it is observed that NC students attended more lectures than PC students though PC students felt they learned more from lectures. Students' overall opinions of lectures were reflective of those noted for phase 2 of the study where only 30% of students surveyed found lectures interesting and only 21% were motivated to read around their lecture material.

Table 2.18: Students' opinions towards lectures (Phase 3)

% number of students	**N**	**Strongly agree / Agree**	**Somewhat /not sure**	**Disagree / Strongly Disagree**	**Mean**
Lectures are interesting	139	47	33	20	3.37
Lectures provide me with more information than notes	138	58	17	25	3.49
Lecture attendance is useful in helping me pass chemistry exams	139	69	18	13	3.83
I need to pay attention in lectures	139	83	9	8	4.22
I am motivated to read around my lecture material	139	32	26	42	2.86
I am only expected to reproduce what was in the lecture notes	138	50	23	27	3.36
I will have to show I understand what was covered in lectures	138	92	6	2	4.30
I will have to use information I learned in lectures to solve unseen problems	138	80	15	5	4.12
I will have to show that I studied outside of what was in the lecture notes	138	47	30	23	3.30

Students' responses to the ASSIST Inventory at the end of the first year highlighted similar trends to that observed at the start of the year (Table 2.19). Students adopted a deep approach over a strategic approach ($p = 0.016$), a deep approach over a surface approach ($p = 0.006$) and a strategic approach over a surface approach ($p = 0.052$). The general trend was also noted for phase 2 of the study however, the differences between the approaches were not significant.

Table 2.19: Student approach to learning at end of year one

Year	Paired-Approach	Diff	σ	t	df	p
Phase 3	Deep-Strategic	0.46	2.18	2.43	132	0.016*
	Deep-Surface	1.03	4.20	2.82	130	0.006*
	Strategic-Surface	0.07	3.88	1.96	126	0.052
Phase 2	Deep-Strategic	0.49	2.96	1.93	135	0.055
	Deep-Surface	0.61	4.19	1.71	137	0.090
	Strategic-Surface	0.22	3.97	0.64	132	0.524

Even though the overall trend was comparable to the start of the year, paired *t*-tests were used to determine whether there was any notable change in students' approaches to learning from their initial indications and that at the end of their first year of university study. In Table 2.20 it is shown that there were significant changes in approach to learning. Students' adoption of 'deep' and 'strategic' approaches significantly decreased from that at the start of the year and their 'surface' approach increased. This was also noted for phase 2 of this study and indeed was a common trend in the previous DCU study[10]. The majority of the subscales significantly changed for both groups; students scored the deep and strategic subscales lower, and the surface subscales scored higher than they did at the beginning of the academic year (Table 2.21). Though the general trend in approach to learning still favoured a deep approach at the end of the first academic year it is of concern that students have shown a decrease in the deep and strategic approaches. This change indicates a decrease in the rating of subscales such as 'seeking meaning', 'relating ideas', 'achieving', 'organised study' and 'time management'. The increase in the surface approach preference relates to an increase in the subscales 'lack of purpose' and 'syllabus boundness'.

Table 2.20: Change in approach to learning at end of 1st year

Group	Scale	A_1		A_2		*t*	*df*	*p*
		Mean	σ	Mean	σ			
Phase 3	Deep	14.28	2.19	13.80	2.58	2.85	121	0.005*
	Strategic	14.11	2.37	13.44	2.25	4.71	120	0.000*
	Surface	12.15	2.42	12.56	2.39	-2.01	117	0.047*
Phase 2	Deep	14.35	2.45	13.31	2.59	4.25	113	0.000*
	Strategic	14.19	2.33	12.81	2.46	8.34	108	0.000*
	Surface	11.80	2.44	12.71	2.44	-4.32	106	0.000*

A_1 = Assist Inventory completed at beginning of year one
A_2 = Assist Inventory completed at the end of year two

Table 2.21: Average score for each subscale indicating change from the start of year one to the end of year two

Approach	Subscales	Phase 3		Phase 2	
		Mean	Change	Mean	Change
Deep	Seeking meaning	13.7	-	13.7	-
	Relating ideas	13.5	-	12.7	-
	Use of evidence	14.5	-	13.9	-
	Interest in ideas	13.3	0	12.6	-
Strategic	Organised study	11.7	-	11.6	-
	Time management	11.7	-	11.0	-
	Alertness to assessment demands	14.7	0	14.3	0
	Achieving	13.5	-	12.7	-
	Monitoring effectiveness	14.8	-	14.7	0
Surface	Lack of purpose	9.6	+	9.7	0
	Unrelated memorising	12.6	0	12.2	0
	Syllabus-boundness	14.4	+	14.5	+
	Fear of failure	14.3	0	14.0	+

(+) indicates a significant increase in preference for subscale
(-) indicates a significant decrease in preference for subscale
(o) indicates no significant change in preference for subscale

It is possible that the changes in students' approaches to learning could be related to the close proximity of the sampling time to students' examinations. It has been mentioned previously that students indicated that they had not applied enough effort to achieve high grades thus they may have adopted a surface approach at the time of the examinations in order to achieve a pass grade. If this is the case, it is a worrying trend as it has been noted in Chapter 1 that a surface approach is only beneficial for short-term recall and does not lead to meaningful learning and thus may have future implications on students learning as they progress through university.

At the end of year one, there are some differences noted in students' approaches to learning when gender and previous chemistry is considered. In Table 2.22, the findings from independent *t*-tests show that male students had a scored a deep approach to learning significantly higher compared to female students who scored a surface approach significantly higher at the end of year one. There appears to be no difference between the gender groups in relation to a strategic approach. This trend was not observed for phase 2 of this study where no significant difference in approach was observed when gender was considered. Analysis of the subscales for the gender groups highlights that male students scored the subscales 'relating ideas' (p=0.009), 'use of evidence' (p=0.005) and 'interest in ideas' (p=0.043) significantly higher than the female students who rated 'fear of failure' (p=0.001) higher than their male colleagues.

Table 2.22: Gender approach to learning at end of 1st year

Group	Scale	Male		Female		*t*	*df*	*p*
		Mean	σ	Mean	σ			
Phase 3	Deep	14.4	2.01	13.3	2.76	2.74	138	0.007*
	Strategic	13.2	2.17	13.3	2.28	0.24	135	0.814
	Surface	12.1	2.71	13.2	2.27	2.58	132	0.011*
Phase 2	Deep	13.6	2.26	13.0	2.81	1.40	134	0.164
	Strategic	12.5	2.24	13.0	2.68	1.14	128	0.255
	Surface	12.4	2.29	13.0	2.63	1.36	130	0.177

In Table 2.23, it is shown that PC and NC students had a similar preference for deep and strategic approaches. However, NC students had a greater preference for a surface approach compared to PC students. A further analysis of the subscales found that NC students scored 'lack of purpose' (p = 0.005) and 'unrelated memorising' (p = 0.000) higher than PC students. It was also noted that PC students scored the strategic subscale 'achieving' (p = 0.003) higher than NC students. This analysis was not carried out for phase 2 of the study as data relating to students' chemistry experience was not obtained as indicated in Table 2.1.

Table 2.23: Approach to learning at end of 1st year (chemistry experience)

Group	Scale	PC		NC		t	df	p
		Mean	σ	Mean	σ			
Phase 3	Deep	14.0	2.61	13.4	2.46	1.364	131	.175
	Strategic	13.6	2.40	12.9	2.05	1.891	129	.061
	Surface	12.0	2.66	13.3	2.21	2.945	127	.004*

In this Section a profile of students at the end of their first year of academic study has been presented. It has been shown that students believe their experience in university has made them more independent and self-confident and that it allowed them to develop knowledge and skills that could be used in a future career. The majority of students liked and felt they learned from lectures and tutorials. The majority of students attended more than 50% of their lectures and tutorials. Students were confident in their ICT and some study skills. It is noted however, that students did not feel they studied interesting courses or content that would allow them to make a difference in the world. There was a significant decrease observed in relation to students' 'learning responsibilities'. They have indicated that they haven't evaluated their learning progress and many have not initiated their own studies. It is also noted that half of the students surveyed did not feel able to ask lecturers questions regarding material they did not understand.

Overall, there appears to be a mismatch in students' expectations for university in terms of their initial motivation and perceived preparedness compared to their experience. It is not certain whether this reduction is due to students' misinterpretation of their abilities, unrealistic expectations or if it's associated with a decrease in motivation or lack of knowing what to expect of them. In relation to a possible lack of effort, it was noted that students attended less lectures and tutorials in the second semester of their first year. It was also highlighted that only 35% of students thought they applied enough effort to achieve high grades in their chemistry. At the end of year one, the overall cohort still showed a tendency for a deep approach to learning compared with a strategic and surface approach. However, it was also noted that there was a significant decrease in their adoption of deep and strategic approaches to learning compared to when they started university. Students also indicated an increased tendency towards a surface approach to learning at the end of their first year of university. It appears that students start university with high expectations relating to interesting content, personal development, engagement with university staff, however, these don't appear to reflect their experience. In the next section, student profiles at the end of their second year of university study are investigated to see whether any further changes are observed.

2.4.4 Student profile at the end of second year of undergraduate study

In section 2.4.3, a comparison was made between students' initial motivations, perceived preparedness and expectations of university with their actual experience during the first year of their undergraduate studies. In this Section, data from the 'Ex_2' survey (see Figure 2.1) will be presented to show whether students' experience during their second year at university has had any influence on their approaches to learning, expectations and preparedness for university. The data discussed will be compared to students' responses given at the end of their first year of study (Ex_1 and A_2). As previously mentioned, the data will be given in relation to phase 3 of this study and will be compared to phase 2 where possible and relevant. Only students who have successfully passed all of their 1st year examinations can progress into 2nd year of university. Thus only students who have made this progression are considered in the analysis.

At the end of the students second year of study, 93% indicated that they liked the course they were studying. This agrees with that observed at the end of their first year of study (92%). Similarly there is little change noted from the end of year one to the end of year two in relation to students' opinions towards the statements from the initial MPE survey regarding students' motivations for attending university (Table 2.24). The majority of students (75%) believed that the university experience has made them more independent and 68% indicated that they were able to 'develop as a person' and 'broaden their horizons'. It is again observed that many students (55%) did not feel they 'studied chemistry in depth' and took 'interesting courses'. The only change noted related to students' response to the statement 'I have developed knowledge and skills that I can use in a career'. Most students (74%) still agreed with this statement though this is a significant decrease compared to the responses given at the end of year one.

Table 2.24: Comparison of students' opinions from the end of year 1 to the end of 2nd year experience (phase 3)

Statement	Strongly Agree / Agree	EX_1	EX_2	Diff	*t*	*df*	*p*
I have developed **knowledge and skills** that I can use in a **career**.	74%	4.36	4.12	-0.24	2.20	49	0.032*
I have learned things that will help me to **develop as a person** and **broaden my horizons**.	68%	4.24	3.94	-0.30	1.82	49	0.075
I have an **active social life** and/or sport in DCU	65%	3.74	3.58	-0.16	1.02	49	0.314
The experience has made me **more independent and self-confident**.	75%	4.04	4.06	0.02	-0.17	48	0.864
I have studied chemistry in depth by taking **interesting and stimulating courses**.	45%	3.24	3.31	0.07	-0.49	48	0.627
I have learned things that might let me **help people**, and/or **make a difference in the world**.	57%	3.38	3.49	0.11	-0.51	46	0.609

Ex_1 = Experience survey completed at the end of year 1
Ex_2 = Experience survey completed at the end of year 2
Diff = Mean difference in students level of agreement between Ex_1 and Ex_2

There were no differences observed for these statements when gender was analysed however there were some differences noted when previous chemistry experience was considered. These differences are shown in Table 2.25. NC students felt they developed less career related knowledge and skills and didn't believe they studied chemistry in dept or interesting courses. There were no differences observed between PC and NC students in this regard in phase 2.

Table 2.25: Difference in experience agreement based on previous chemistry experience at the end of year two (phase 3)

	PC	**NC**	***t***	***df***	***p***
I have developed knowledge and skills that I can use in a career	4.24	3.72	2.12	57	0.038*
I have studied chemistry in depth by taking interesting and stimulating courses	3.61	2.67	3.50	57	0.001*

In Table 2.26, a comparison between students' responses in relation to their perceived preparedness for university study given at the end of year one to those expressed at the end of year two are shown. Students were still very confident in terms of their ICT skills. However, it was noted that female students were less confident than male students ($p = 0.017$). The majority of students (68%) were confident about being able to complete written assignments and lower confidence in planning and making oral presentations (48%). There was a significant increase in students' comfort in working in groups ($p = 0.009$); however, student responses still highlighted that only 48% felt able to ask lecturers for help when they needed it. The majority of students (73%) noted that they have taken responsibility for their learning and there was a significant increase in students' ability to study in a 'time effective manner', although only 35% agreed with this statement. Other than this change, there were no other significant changes observed in relation to the 'learning responsibility' grouping. However, there were differences observed in this grouping when previous chemistry experience was taken into account. In Table 2.27, these differences are noted. NC students felt less able to initiate their own studies and less able to take responsibility for their learning. As noted in Table 2.1, the a comparison based on previous chemistry could not be determined for phase 2 of the study. An overall comparison of phase 3 and phase 2 studies indicated that there were no significant differences between the students' responses provided at this stage of their university studies.

Table 2.26: Comparison of students' responses between the end of first year (Ex_1) and the end of their second year of study (EX_2) (phase 3)

Statement	Agree	EX_1	EX_2	Diff	*t*	*df*	*p*
I know what is **expected** of me **academically** in university	61%	3.64	3.72	0.08	-0.70	49	0.485
I have **worked independently** without much direction from a teacher	59%	3.78	3.62	-0.16	1.16	49	0.252
I have **initiated my own study** activities	63%	3.65	3.77	0.12	-0.80	47	0.428
I am able to **plan my study** in a time effective manner to **meet all my deadlines**	35%	2.98	3.55	0.57	-3.64	48	0.001*
I have **taken responsibility** for my own **learning**	73%	3.76	3.80	0.04	-0.34	49	0.735
I have **asked for help** from my lecturers/tutors when needed	48%	3.20	3.20	0.00	0.00	49	1.000
I am confident about my ability to **use a computer**	86%	4.04	4.18	0.14	-0.98	49	0.332
I am comfortable when **working in groups**	88%	3.80	4.22	0.42	-2.73	49	0.009*
I am comfortable about my ability to **complete written assignments**	68%	4.04	3.76	0.28	1.96	49	0.056
I feel **able to ask my lecturer** questions about material I don't understand	36%	3.22	3.18	0.04	0.23	49	0.816
I have **evaluated my own progress**	39%	3.18	3.29	0.11	-0.53	48	0.601
I have **organised my own life** generally	59%	3.58	3.70	0.12	-0.92	49	0.360
I am confident in planning and making **oral presentations**	48%	3.34	3.32	0.02	0.14	49	0.892
I can **use internet** and other resources to gain information	92%	4.56	4.38	0.18	1.70	49	0.095

Ex_1 = Experience survey completed at the end of year 1
Ex_2 = Experience survey completed at the end of year 2
Diff = Mean difference in students level of agreement between Ex_1 and Ex_2

Table 2.27: Difference in level of agreement to 'preparedness' experience statements based on previous chemistry experience at the end of year two (phase 3)

Statement	PC	NC	*t*	*df*	*p*
I have initiated my own study activities	3.90	3.28	2.35	55	0.023*
I am able to initiate my own study activities	3.90	3.28	2.66	57	0.010*
I am able to take responsibility for my own learning	4.02	3.50	2.42	57	0.019*

Students' perceived abilities in relation to the 'learning responsibility' grouping indicated at the end of year two were compared to their actual experience in the second year of their university studies (Table 2.28). No differences were observed in relation to students' perceived ability to initiate their own studies, to work independently or to take responsibility for their studies. However, it was seen that students did not organise their lives, plan their study, or evaluate their progress compared to their indicated ability to do so.

Table 2.28: Comparison of students' perceived ability in terms of learning responsibility at the end of year two and their actual experience at the end of year two (phase 3)

	Statement	Mean	*t*	*df*	*p*
1	**I have worked** independently without much direction from a lecturer	3.6	-.293	68	.770
	I am able to work independently without much direction from a lecturer	3.7			
2	**I have initiated** my own study activities	3.7	-.779	66	.439
	I am able to initiate my own study activities	3.8			
3	**I have planed my** study in a time effective manner to meet all my deadlines	2.9	-4.202	66	.000*
	I am able to plan my study in a time effective manner to meet all my deadlines	3.4			
4	**I have taken** responsibility for my own learning	3.8	-.869	68	.388
	I am able to take responsibility for my own learning	3.9			
5	**I have asked** for help from my lecturers/tutors when needed	3.2	-3.156	66	.002*
	I am willing to ask for help from my lecturers/tutors when needed	3.6			
6	**I have evaluated** my own progress	3.2	-3.363	66	.001*
	I am able to evaluate my own progress	3.5			
7	**I have organised** my own life generally	3.6	-2.860	68	.006*
	I am able to organise my own life generally	3.9			

In the Ex_2 survey students gave some indications of their intensions towards their study at the end of their second year of study. 79% of students believed they had committed enough effort to pass their examinations with only 35% noting that they applied enough effort to achieve high grades. However, at the end of second year, students' responses highlighted that they were spending an average of eight hours a week studying which was an increase of three hours compared to the end of first year. Phase 2 students indicated that they spent six hours a week studying. Students (89%) believed lecture and tutorial attendance was related to good performance in chemistry examinations, as was the case at the end of first year. In Table 2.29, students' opinions regarding lectures are noted. It is shown that the majority of students felt that they had to show an understanding of material covered in lectures and 61% noted that they would have to show that they studied material outside of lecture content to do well in examinations. These findings regarding students' opinions of lectures were mirrored by those observed in phase 2 of this study.

Table 2.29: Percentage number of students' opinions towards lectures at the end of year two (phase 3)

Statement	N	Strongly agree / agree	Somewhat /not sure	Disagree / strongly disagree	Mean
I am only expected to reproduce what was in the lecture notes	70	36	23	41	2.9
I will have to show I understand what was covered in lectures	70	94	6	0	4.4
I will have to use information I learned in lectures to solve unseen problems	70	90	6	4	4.3
I will have to show that I studied outside of what was in the lecture notes	70	61	21	18	3.6

In Figure 2.1, it was highlighted that ASSIST data were collected at the end of the 2nd year of undergraduate study. It is noted (Table 2.1), that the sample size of the data collected at this stage were quite small in comparison to the cohort; 29 for phase 3 and 58 for phase 2. It is not deemed appropriate to make the assumption that the results observed are reflective of the cohorts of the students, however the trends will be presented to give the general picture for the students who did complete the surveys.

In Table 2.30, the approach to learning at the end of year two is highlighted. For both phases of this study it is observed that students do not have an approach preference. Their responses to the ASSIST Inventory show similar scores for all three approaches at the end of their second year of study. This is observed for both phases of this study and in the previous DCU study[10].

Table 2.30: Student Preference for approach to learning at end of year two

Year	Paired-Approach	Diff	σ	t	df	p
Phase 3	Deep-Strategic	-0.01	2.05	0.03	24	0.977
	Deep-Surface	1.39	4.85	1.43	24	0.164
	Strategic-Surface	1.32	4.36	1.57	26	0.127
Phase 2	Deep-Strategic	0.38	3.23	0.85	50	0.398
	Deep-Surface	0.02	4.13	0.03	49	0.980
	Strategic-Surface	-0.46	3.75	-0.86	47	0.397

In Table 2.31, the change in approach to learning from the end of year one to the end of year two is presented. This data only considers the students who completed both surveys. Note that they sample sizes are small and therefore the trends observed must be considered with caution. It is observed that students' tendency towards a deep approach decreased and their scores for the surface approach increased. There was no recorded change for the strategic approach to learning. The increase in preference for a surface approach was also recorded for phase 2 of this study.

Table 2.31: Students change in approach to learning from end of year one to end of year two

Group	Scale	A_2		A_3		t	df	p
		Mean	σ	Mean	σ			
Phase 3	Deep	14.6	2.46	13.8	2.34	2.80	21	0.011*
	Strategic	14.4	1.97	14.1	2.17	0.92	22	0.370
	Surface	11.8	1.94	12.9	2.76	-2.64	22	0.015*
Phase 2	Deep	13.2	2.91	13.5	2.88	-1.10	42	0.277
	Strategic	12.8	2.99	13.2	2.68	-1.11	39	0.273
	Surface	12.6	2.8	13.7	2.49	-2.70	36	0.010*

A_2 = Assist Inventory completed at the end of year one
A_3 = Assist Inventory completed at the end of year two

In Table 2.32, the overall changes observed in students' approaches to learning from the beginning of their studies (A_1) to the end of second year (A_3) are presented. Again cognisance and caution of the small sample sizes at the end of year two must be considered. An overall trend indicated a decrease in students' tendencies for deep and strategic approaches to learning. It is also recorded that students' tendency for a surface approach has increased since they started their university studies. The subscales 'lack of purpose', 'unrelated memorising' and 'syllabus boundness' all significantly increased for phase 3 of the study. Although there is no overall difference in approach at the end of second year, it is of concern that the surface subscales have significantly increased. These findings agree with those recorded in the previous DCU study[10].

In Table 2.33, a comparison of students' approaches to learning at the end of year two based on gender groups is given. Once again, it is noted that the sample sizes were small and that the data only represents students who completed the survey. For phase 3 of the study there are no differences between the approaches to learning that male and female students adopt. In phase 2, it is observed that female students had a greater tendency towards a strategic approach to learning. An analysis of students' approaches to learning based on previous chemistry background was not carried out as the sample sizes were too small to compare those that completed the inventory.

Table 2.32: Overall change in students approach to learning from the end of year one to the end of year two

	Phase 3		Change	Phase 2		Change
Sampling	A_1	A_3		A_1	A_3	
N*	164	29		175	58	
Deep	14.28	14.18	-	14.21	13.45	0
Strategic	14.19	14.28	-	14.33	13.19	-
Surface	12.22	12.86	+	11.87	13.79	+
Seeking Meaning	14.24	14.15	0	14.37	14.21	0
Relating Ideas	14.13	13.68	0	14.28	12.66	-
Use of evidence	14.96	15.19	-	14.58	14.28	0
Interest in ideas	13.88	13.96	0	13.60	12.69	0
Organised studying	12.69	12.68	0	13.37	11.19	-
Time management	13.16	13.21	-	13.80	11.37	-
Alertness to assessment demands	14.79	15.96	0	14.52	15.05	0
Achieving	14.75	14.61	0	14.76	13.02	-
Monitoring effectiveness	15.56	14.93	-	14.86	15.34	0
Lack of purpose	8.72	9.54	+	9.32	10.75	0
Unrelated memorising	12.63	12.86	+	12.33	13.78	0
Syllabus-boundness	13.32	14.15	+	12.98	14.71	+
Fear of failure	14.27	14.86	0	13.17	16.04	+

A_1 = Assist Inventory completed on entry to university
A_3 = Assist Inventory completed at the end of year two

(+) indicates a significant increase in preference for subscale
(-) indicates a significant decrease in preference for subscale
(o) indicates no significant change in preference for subscale

Table 2.33: Approach to learning for gendered groups at the end of year two

Group	Scale	Male		Female		*t*	*df*	*p*
		Mean	σ	Mean	σ			
Phase 3	Deep	14.30	2.21	13.90	2.75	0.31	22	0.772
	Strategic	14.70	2.05	14.10	2.33	0.64	25	0.527
	Surface	12.70	3.19	12.80	2.55	1.01	24	0.920
Phase 2	Deep	13.80	2.22	13.26	3.20	0.67	51	0.503
	Strategic	11.90	2.92	13.80	2.16	2.58	47	0.013*
	Surface	13.33	1.87	14.07	2.56	1.04	48	0.306

In summary, in this section it was noted that there are few changes in students' experiences noted from the end of first year to the end of second year. Students mostly like their course but do still express difficulties regarding planning their study, evaluating their learning progress and asking for help when required. Students at the end of the of their second year of study have similar tendencies towards deep, strategic and surface approaches to learning which highlights a further increase in tendency towards a surface approach and decrease in adoption of deep and strategic approaches compared to when students enter university. From these findings, it suggests that by the end of first year students have settled into a pattern of study at university that they continue in second year of their study. This highlights the importance of addressing issues such as students' expressions of difficulty in terms of 'learning responsibility' in first year of undergraduate courses.

2.4.5 Correlations of student interaction with learning supports and student profiles with academic performance

In the previous Sections, data regarding engagement with learning supports and student profiles (motivations, expectations, preparedness, and approaches to learning) at various stages of their undergraduate studies have been given. In this Section, students' academic performance will be examined in relation to the profiles previously presented. The findings will be given in two parts, (A) correlation of students' examination performance in relation to their engagement with learning supports from the pilot study and (B) correlation of students' examination performance in relation to the profile generated at the end of students first year of university study.

Part A: Correlation of students' examination of performance in relation to their engagement with learning supports

It was previously discussed (Section 2.1) that the VLE support provided was made available for the organic component of students' first year chemistry lectures. In the same semester students also studied physical chemistry. In order to look at possible influence of the VLE support on students' academic performance, the extent of students' engagement with the VLE is compared with students overall academic performance in the chemistry module and also with their performance in the physical chemistry component. In Table 2.34, students' engagement with the VLE support in terms of 'mean number of resources accessed' is investigated in relation to their academic performance in chemistry examinations. It is shown that students who obtained a grade above 40% in the organic section accessed significantly more resources than students who were awarded less than 40%. Students who accessed more resources also performed better in the overall examination and in the physical examination component. This perhaps indicates that the more conscientious or motivated student will use resources available or indeed that these students may have succeeded whether a VLE support was or was not available.

Table 2.34: Student overall examination success and comparison to mean resources used in the VLE (phase 1)

Chemistry examinations	Score	N	Mean no. resources used	*t*	*p*
Overall	>40%	137	10.55	4.15	0.000*
	<40%	44	7.57		
Organic	>40%	123	10.51	3.33	0.000*
	<40%	58	8.38		
Physical	>40%	141	10.43	4.12	0.000*
	<40%	40	7.70		

There was a positive correlation between lecture note access and student examination performances in the organic component of the chemistry module. In Table 2.35, it is shown that a greater percentage of students who accessed weekly lecture notes scored above 40% of in the organic component e.g. 70% of students who accessed week two lecture notes scored above 40% in the organic component whereas only 41% of those who had not accessed week two lecture notes scored above 40% in the organic component. It is worth noting that this data only considers whether the students had accessed the resource themselves; it does not account for students receiving copies from others or even if students actually used the resource in their learning, after accessing it.

Table 2.35: Student performance in organic chemistry examination in relation to lecture note access (phase 1)

Resource	Proportion of students who scored above 40% in the organic component		*p*
	Accessed	Not Accessed	
Wk1 notes	70%[b] (N=167)	43% (N= 14)	0.036*
Wk3 notes	70% (N=164)	41% (N= 17)	0.013*
Wk4 notes	70% (N=162)	43% (N= 19)	0.036*
Wk5 notes	73% (N=156)	36% (N= 25)	0.000*
Wk6 notes	71% (N=150)	52% (N= 31)	0.032*

[b] % value in table refers to % of N value

Quiz access was also significant in terms of organic examination success (p = 0.008). 74% of those who accessed the quizzes scored above 40% in the chemistry examination (N=144) and 54% of those who didn't access any of the quizzes scored below 40% (N=37). The students who scored above 40% in the examination accessed an average of 3 quizzes and those who scored below 40% in the examination accessed an average of 2 quizzes. Quiz attempts versus academic performance was further examined with respect to students' prior knowledge of chemistry. PC students who attempted Quiz 1 did significantly better in the overall chemistry examination (p = 0.038) than those who didn't attempt the quiz. There was no other significance for the remaining quizzes for this group. NC students who attempted quiz 1 and 2a did significantly better in their chemistry examination than those who didn't (Table 2.36). These differences were also observed for the remaining quizzes but the magnitudes of the differences were not statistically significant. These results highlight that students who interacted with the module supports did better in their chemistry examinations. However, it is not suggested that it is as a direct result of the provision of the support. It is merely an indication that students who were motivated / interested in using all available help in their studies did better in their examinations. It was observed that in particular, the effect of interacting with the on-line quizzes was more pronounced for students NC students than PC students.

Table 2.36: NC students' examination performance in relation to quiz access (phase 1)

Quiz	Usage [a]	N	Mean % Overall exam	Mean % Organic	Mean % Physical	Overall Exam	Organic	Physical
Quiz 1	Didn't	42	39.2	36.0	42.5	0.015*	0.050*	0.016*
	Did	36	49.5	46.1	52.9			
Quiz 2a	Didn't	60	40.8	37.0	44.5	0.005*	0.010*	0.017*
	Did	18	54.6	56.6	56.7			

[a] Did/ Didn't refers to those who accessed the quiz

Part B: correlation of students' examination performance in relation to the profile generated at the end of students first year of university study

In Section 2.4.3, students' responses to questions regarding their first year experience were presented. These questions related to students' motivation, preparedness, expectations and approaches to learning. These responses have been correlated with students academic grades achieved at the end of their first year of university study. The grades used for this analysis were: (1) students overall chemistry grade relating to the lecture module taken (Chemistry Mark), (2) the continuous assessment component of the chemistry lecture module (CA), (3) the examination component of the lecture module (Written), and (4) students chemistry laboratory grade (Lab).

In Table 2.37, the results relating to the correlation of academic marks and students' responses to the motivation statements used on the 'Ex_1' survey are given. There are no correlations observed regarding the intrinsic statements that relate to students becoming 'more independent', 'learning things to make a difference in the world' or 'learning things to help them broaden their horizons'. Student happiness in terms of attending DCU correlated with their academic performance with respect to their overall chemistry grade, their continuous assessment grade and their laboratory grade. There were also positive correlations noted between academic performance and students who felt that they 'developed knowledge and skills for use in a career' and that they 'studied interesting chemistry courses'. Interestingly, a negative correlation between academic performance and students' active participation in sporting and social life in DCU was observed.

Table 2.37: Pearson correlation of students' academic performances with their responses to the motivation statements at the end of year one (phase 3)

Statement	N	Chemistry	CA	Written	Lab
I have developed **knowledge and skills** that I can use in a **career.**	139	**0.293†**	**0.195***	**0.293†**	**0.334†**
I have learned things that will help me to **develop as a person and broaden my horizons.**	139	0.143	0.107	0.137	0.155
I have **an active social life** and/or sport in DCU	138	**-0.273†**	-0.067	**-0.336†**	**-0.211***
The experience has made me more **independent and self-confident.**	139	-0.077	-0.079	-0.062	0.012
I have studied chemistry in depth by taking **interesting and stimulating courses.**	138	**0.314†**	**0.202***	**0.318†**	**0.366†**
I have learned things that might let me **help people, and/or make a difference in the world.**	137	0.033	0.019	0.035	0.114
I am happy I went to this university	138	**0.203***	**0.211†**	0.155	**0.243†**

* 95% Significant correlation
† 99% Significant correlation

In Table 2.38, students' perceived preparedness for university study at the end of year one is correlated with their academic performance. There are no correlations observed when ICT confidence is considered. This is not unsurprising as the majority of students indicated high levels of confidence at this stage. Student confidence in completing written assignment correlates with academic performance in laboratories, though it has no relation on the other academic grades awarded. A similar finding was observed in relation to students who were willing to ask for assistance when needed; this also only relates to academic performance in laboratories. The most prominent positive correlations between student responses and academic performance relate to the 'learning responsibility' statements. It is observed that there is a relationship between students who 'took responsibility for their learning', 'were able to plan their study to meet deadlines', who 'initiated their own study' and academic performance in the overall lecture grade, the written examination and students laboratory grades. The final positive correlation observed was between students' ability to work independently without teacher direction and performance in laboratories. From the findings it is clear that 'learning responsibility' is an important factor in students' academic performance. Previously, it was noted that on when entering university and at the end of the first and second year of university study, students have indicated that this is an area that they are not fully confident suggesting that this is an area that needs to be addressed in the first year of undergraduate courses.

In the analysis of examination performance and VLE engagement it was noted that the conscientious student who engaged with the VLE received better academic grades. The same finding has been found when students' attendance at lectures and tutorials are investigated. In Table 2.39, Pearson correlations show that there are positive correlations between students' attendance at lectures and tutorials and their academic performance in all of the chemistry assessment elements at the end of year one.

Table 2.38: Pearson correlation of students perceived preparedness for university at the end of year one and their academic performance (phase 3)

	N	Chemistry	CA	Written	Lab
I know what is **expected of me academically** in university	139	0.047	-0.58	0.096	0.025
I have **worked independently** without much direction from a teacher	139	0.156	0.101	0.157	**0.252†**
I have **initiated my own study** activities	139	**0.190***	0.058	**0.228†**	**0.248†**
I am able to **plan my study** in a time effective manner to **meet all my deadlines**	139	**0.220†**	0.030	**0.285†**	**0.189***
I have **taken responsibility** for my **own learning**	137	**0.247†**	0.119	**0.272†**	**0.230†**
I have **asked for help** from my lecturers/tutors when needed	139	0.127	0.096	0.121	**0.207***
I am confident about my **ability to use a computer**	138	-0.069	0.002	-0.096	0.013
I am comfortable when **working in groups**	139	-0.086	0.055	-0.148	-0.101
I am comfortable about my ability to **complete written assignments**	138	0.121	0.071	0.126	**0.184***
I feel **able to ask my lecturer questions** about material I don't understand	139	0.118	-0.008	0.165	0.065
I have **evaluated my own progress**	139	0.037	-0.033	0.070	0.111
I have **organised my own life generally**	139	0.034	-0.042	0.070	0.018
I am confident in planning and making **oral presentations**	139	0.050	0.078	0.025	0.042
I can **use internet** and other resources to gain information	139	0.041	0.105	-0.001	0.004

* 95% Significant correlation
† 99% Significant correlation

Table 2.39 Pearson correlation of student lecture and tutorial attendance with their academic performance at the end of year one (phase 3)

Statement	N	Chemistry	CA	Written	Lab
Semester one lectures	139	0.348†	0.337†	0.2904†	0.351†
Semester one tutorials	138	0.426†	0.518†	0.295†	0.311†
Semester two lectures	138	0.469†	0.379†	0.431†	0.464†
Semester two tutorials	136	0.500†	0.651†	0.320†	0.387†

†99% Significant correlation

Students' approaches to learning have also been found to correlate with academic performance. In Table 2.40, it is noted that there are positive correlations between a deep approach and academic performance in students overall chemistry grade, the written component and the laboratory grade. The same observation is noted for the strategic approach. It is observed that the Pearson correlation numbers are greater for the strategic approach compared to the deep approach. A negative correlation between all of the assessment components analysed and a surface approach is shown. The findings suggest that adopting deep and strategic approaches to learning leads to better academic success than a surface approach. Similar findings were reported in the previous DCU study[10], which highlighted consistent positive correlations with a strategic approach and academic performance and consistent negative correlations with surface approaches and academic performance. In that study correlations for a deep approach were less consistent but overall positive correlations with academic performance were reported.

Table 2.40: Pearson correlation between approach to learning and academic performance at the end of year one (phase 3)

Approach	N	Chemistry	CA	Written	Lab
Deep	140	.239†	.051	.296†	.250†
Strategic	137	.309†	.156	.337†	.303†
Surface	134	-.395†	-.319†	-.366†	-.360†

† 99% Significant correlation

Conclusions

In conclusion, in this work an initial pilot study was carried out to investigate students' engagement with learning supports. The findings suggested that there are varied patterns of engagement with learning supports but that there is an overall general trend of decreasing engagement with learning supports as the module progresses followed by a short increase in engagement during exam study periods. It was also shown that the more conscientious student who engaged with the learning supports achieved higher academic results.

In this follow on study into student profiles (phase 2 and phase 3) student profiles have been generated and correlations between student profile and academic achievement have highlighted several factors that impact on student achievement. These factors relate to 'student interest', student 'learning responsibilities', 'student attendance' and 'students' approaches to learning'. It has been shown that students who felt that they 'developed knowledge and skills which they could use in a career' and who believed they studied 'interesting and stimulating courses' performed better in their examinations. Students who were able to 'initiate their own studies', 'to plan their study to meet deadlines' and who 'took responsibility for their learning' also achieved better examination grades. Positive correlations between student attendances at lectures and tutorials were shown to relate to academic performance and finally it was shown that students who adopted deep and strategic approaches to their learning achieved better examination grades.

In Section 1.2.3, it was noted from the literature that mismatches between students' perceptions and expectations for university study can lead to poor performance and high-drop out rates. It was also noted that students find the transition into third level difficult, especially in terms of working independently, managing their time and adopting successful study techniques. It is apparent that the findings in this study reflect the literature discussed previously. It is also evident that the areas that correlate with academic achievement are those that have become problem areas by the end of first year and by the end of second year i.e. increase in surface approach, reduction in perceived preparedness of learning responsibilities, reduction in students' engagement. The implications of these findings are that efforts must be made to encourage more students' interaction with their respective courses in conjunction with encouraging students to adopt a deep approach to their learning. It is suggested that these may be achieved through lectures that explicitly show the relevance of their content to real-life applications and viable career paths and lecture-linked laboratory sessions and through continuous and appropriate assessment methods. In Figure 1.5, it was identified that the quality of student learning is related to their motivations, approaches to learning and perceptions of learning environments. The findings presented in this Chapter have supported this. It was also noted in Chapter 1, that student learning is further influenced by the teaching, teaching environment, assessment systems etc. In Chapters 3 and 4 the rationale and introduction of an undergraduate chemistry module implemented to address these very issues is presented.

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Chapter 3:

Implementation and development of an undergraduate chemistry laboratory module

In Chapter 1, an overview of research literature relating to student learning, problem solving, learning environments and assessment has been presented. In this chapter the focus is on literature concerning undergraduate laboratories. This literature will serve as a supporting foundation for the development and implementation of a laboratory module for first year university general chemistry. The aims of this laboratory module will be discussed in addition to the mechanisms used to implement them. In Chapter 4 details of the evaluation of this module will be given.

3.1 Laboratory literature overview

Laboratory work is an integral part of chemistry teaching. It is an essential part of undergraduate chemistry courses and provides a setting for training not just in practical hand and instrument skills, but also in other skills such as planning, recording, interpreting and working in teams[1]. Carnduff and Reid identify several reasons justifying the inclusion of laboratory work in undergraduate chemistry courses (Table 3.1).

Table 3.1: List of reasons for laboratory work, adapted from Carnduff and Reid[1]

- Illustrating key concepts
- Seeing things for 'real'
- Introducing equipment
- Training in specific practical skills and safety
- Teaching experimental design
- Developing observational skills
- Developing deduction and interpretive skills
- Developing team working skills
- Showing how theory arises from experimentation
- Reporting, presenting, data analysis and discussion
- Developing time management skills
- Enhancing motivation and building confidence
- Developing problem solving skills

In addition to the reasons for including laboratory work in undergraduate chemistry courses, they also highlight six aims of laboratory work namely: preparation for the world of work, practical skills, methods of science, making chemistry real, personal skills and intellectual skills. Within the published literature there are many similar suggestions for the purpose and aims laboratories[2,3,4,5]. Garratt's aims of laboratory work are reflective of a general consensus with the literature and are shown in Table 3.2[6].

Table 3.2: Aims of practical work adapted from Garratt[6]

Provide opportunities to develop:	**Provide experience of:**
▪ Technical skills	▪ Designing the experiment
▪ Confidence in lab work	▪ The experimental basis of theory
▪ Observational skills	▪ Link between theory and practice
▪ Awareness of safety	▪ Consolidating subject knowledge
▪ Recording skill	▪ The process of science
▪ Data manipulation	
▪ Data interpretation	
▪ Presentational skills	
▪ Report writing	
▪ Oral communication	

Although there is agreement regarding the aims of laboratory work, many argue that in practice these potential learning opportunities are rarely achieved[7,8,9]. Bennett and O'Neale note that at undergraduate level there are two main problems with laboratories; a lack of student participation in experimental design and the poor use of the time available[3]. They argue that there is excessive repetition on simple manipulation using up time that could be better spent on progressive skill development. Domin used Bloom's Taxonomy to evaluate 10 undergraduate general chemistry manuals[10]. He found that the majority focused on lower order cognitive skills (knowledge, comprehension and application) and had very little emphasis on higher order cognitive skills such as analysis, synthesis and evaluation. Similar findings have been reported previously by Meester and Maskill[11].

There are various methods of instruction used in laboratory work. Domin's taxonomy of laboratory instruction provides a helpful overview of these methods[12]. He describes four types of instruction; expository, problem-based, discovery and inquiry, where he differentiates between the types of instruction based on three descriptors; outcome, approach and procedure (Table 3.3).

Table 3.3: Taxonomy of Laboratory Instruction from Domin[12]

	Descriptor		
Style	**Outcome**	**Approach**	**Procedure**
Expository	Predetermined	Deductive	Given
Problem-based	Predetermined	Deductive	Student generated
Discovery	Predetermined	Inductive	Given
Inquiry	Undetermined	Inductive	Student generated

The outcome of a laboratory can be predetermined or undetermined i.e. it is known or unknown. A laboratory task though predetermined may be known by the lecturer but not by the student. The approach can be either deductive or inductive where Domin defines a deductive approach as one "in which the students apply a general principle toward understanding a specific phenomenon" whereas an inductive approach is one in which students derive a principle through observation of certain situations[12]. The final component of the taxonomy is the procedure which can be given to the student or student generated. The four styles of laboratory instruction will now be discussed.

The expository laboratory (also known as the traditional approach) is the most commonly used method of laboratory instruction at both secondary and tertiary levels. This model can be beneficial when teaching manipulative skills and data collection/recording. It is advantageous in terms of cost and logistics, especially with large cohorts. The pre-described nature of the experiments means that many students can complete a given task in an allotted time schedule, with minimal health and safety concerns, and without the need, for unforeseen equipment and costs. However, the traditional laboratory is often criticised for its 'cookbook' or 'recipe' nature where it can reduce the activity to following a step by step procedure, until the predetermined outcome is achieved. The expository laboratory tends to involve students carrying out a procedure to determine an outcome which they verify by comparison with a known result. "*Never are the students asked to reconcile the result, as it is typically used only for comparison against the expected result, not confronted with a challenge to what is naively predictable*"[13]. "*It is possible to reach the end of a laboratory period having learned nothing with the exception of some hand skills. It is even possible to obtain the 'right answer' or good crystals without knowing why*"[14]. In effect, many students carry out the laboratory activity without, or needing to, understand why or what they are doing. Though this instruction model does have its advantages many of Garratt's aims (Table 3.2) are not realised. Little opportunity is provided for designing experiments, data interpretation, making presentations and developing communication skills. The model has also been criticised for giving unrealistic impressions of scientific experimentation and often being an ineffective environment for teaching concepts and one in which no meaningful learning takes place[15,16,17,18].

Domin's description of problem-based laboratory instruction differs from the traditional laboratory in that the procedure is student generated. The instructional method is a variation of problem based learning which is a student centred instructional method. It is one in which 'authentic problems' are used as the focus to motivate students to learn new knowledge and develop new skills. The first recorded example of PBL was used in 1969 at McMaster University, Canada. It was developed there in a tutorial format to teach science and clinical practice[19]. Since its original appearance, many documented uses of PBL can be found within the literature across a wide spectrum of fields including business, law and the physical sciences. There are many explanations of PBL within the published literature[19,20,21,22]. Boud and Felletti state that PBL "*is a way of constructing and teaching courses using problems as the stimulus and focus for student activity…. It is a way of conceiving the curriculum as being centred upon key problems in professional practice*". Engel would argue that PBL is not a teaching strategy but an approach to learning where the PBL student learns skills to help them to become capable of coping with modern life and contributing to society and not just knowledge. Benefits of using a PBL, such as adoption of a deep approach, increase in intellectual development, increase in motivation and enjoyment as well as improvements in application of knowledge and development of professional skills have been reported within the literature [23,24,25]. The key disadvantages of PBL documented refer to difficulties in problem design, preparation and delivery time constraints, logistics and staffing needs / training as well as a decrease in the amount of knowledge base covered[26,27,21,28,29]. In the physical sciences there are many cases of PBL being used as an alternative to standard lectures series and have reported similar findings[30,31,32,33,34].Over the past ten years there has been more explicit documentation of the use of PBL within the physical sciences. This is perhaps in response to several reports and papers that note a need to develop skills (communication skills, critical thinking, problem solving ability, evaluation, interpretation and practical skills, data-processing and research skills) as well as content knowledge for graduate employment[35,36,37].

There are many reports of the use of PBL in chemistry laboratories at all levels of undergraduate courses[38,39,40,41]. Kelly and Finlayson adapted an entire first year undergraduate chemistry laboratory module into a PBL format[38]. The module included the three main chemistry areas (physical, inorganic and organic) and incorporated a pre-lab element in which students were initially given the problem to prepare before attending the laboratory. They reported that their implementation didn't compromise on quantity or quality of content and/or practical work. They noted initial issues with student stress and student's background in chemistry, in that a certain level of background knowledge was required for students to engage with the content. However, by the end of the year they indicate reduced student frustration and that 83% of the students favoured a PBL approach compared to a traditional approach. In addition they note that the module allowed for better skills development, understanding of concepts and the experimental process where students had opportunities to plan, implement, and analyse their own experiments. McGarvey adapted traditional 2nd year physical chemistry experiments into PBL experiments[39]. He notes 'as well as being more demanding and frustrating they can also be more interesting, flexible and stimulating than the traditional style of laboratory practical'. He reports issues relating to the laboratory demonstrators in that they thought the laboratories were a good idea but they found them difficult since they didn't have a laboratory script to follow and were often conscious that they might give the wrong advice. He reports that this was picked up on by the students and heightened their frustration as they, the students, lacked confidence in the advice they received. McGarvey highlights the need for demonstrator training both in the theoretical aspects of the tasks and in being able to proactively engage the students. He suggests that it may not be desirable to completely remove the expository laboratory since different laboratories serve different purposes but that the implementation of some PBL style laboratories may train and encourage students to take a more critical view of expository laboratories and thus learn more from them.

Following on from the problem based instruction, Domin's taxonomy (Table 3.3) describes the discovery led instructional model which differs from the traditional laboratory in that it uses an inductive approach where students derive a principle through observations of the phenomenon. Again the outcome is predetermined (by lecturer only) and the procedure is given, albeit minimally guided in this situation. The thinking is that by deriving the principle for themselves, students will internalise the learning thus making it more motivational, more meaningful and lead to greater retention of knowledge. Ricci and Ditzier reported on an introduction of a discovery approach in a first year undergraduate general chemistry course[42]. They introduce new topics in chemistry through discovery learning in the laboratory before they are met in lecturers. They argue that the discovery approach emphasises the connections between theory and the supporting empirical data. They note positive results regarding their implementation, specifically in terms of improved attitude on behalf of both faculty and students. Other positive reports and examples of a discovery approach can be found within the literature[43,44,45] although there is little mention of any changes in student grades or knowledge. Discovery learning has been criticised as an instructional laboratory method in that it is time consuming to develop and implement, and it is also argued, that if students have not been given a theoretical introduction, they will not know where or how to look for the appropriate observation and indeed they will not identify what they are looking for[15,46]. Domin questions the extent to which discovery instruction is actually a 'discovery' considering the practical situation where a teacher leads the students to and tells them the discovery or in the case when one student makes the discovery and tells the rest. In effect this turns discovery into an expository exercise[12].

The fourth instructional method outlined by Domin is inquiry (Table 3.3). It is a variation of inquiry based learning (IBL), the use of which has been reported in the literature since the 60s[47] and is still being advocated in new curricula today[48,49,50].

> *"Inquiry is a multifaceted activity that involves making observations; posting questions; examining books and other sources of information to see what is already known; planning investigations; reviewing what is already known in light of experimental evidence; using tools to gather, analyse, and interpret data; proposing answers, explanations, and predictions; and communicating the results. Inquiry requires identification of assumptions, use of critical and logical thinking, and consideration of alternative explanations"*[51].

As with the previous three instructional models, inquiry has its plaudits and critics. Some early implementations of IBL reported poor outcomes which reviewers have since linked to poor dissemination and implementation of the methodology and specifically the expectation that students would be able to carry out authentic open inquiry without being given the opportunity to develop the necessary skills through a progression of experience of the lower levels of inquiry instruction[8,12] Bell *et al*[52] stress that students must have experience of structured or guided inquiry before they can tackle open inquiry which is supported by Baird who said that; "*purposeful inquiry does not happen spontaneously – it must be learned*"[53]. Domin's taxonomy of inquiry instruction is an example of open inquiry where the outcome is undetermined, the approach inductive and the procedure student generated. To do this requires students to use many higher order skills. In practice for open-ended inquiry, students must "*formulate the problem, relate the investigation to previous work, state the purpose of the investigation, predict the result, identify the procedure and perform the investigation*"[15]. This gives them the opportunity to develop and practice skills such as hypothesising, explaining, criticising, analysing, judging evidence, inventing and evaluating arguments[54]. Since this form of instruction is student focussed, students develop a sense of ownership and they are more likely to be aware of the aim and purpose of what they are doing. This is advantageous as Berry *et al* point out that cognitive engagement improves when these factors are satisfied[55]. Many studies advocate the use of inquiry instruction and have noted advantages including greater student motivation, engagement and improved attitudes towards science[56,57]. In addition Hofstein *et al* have shown that students partaking in inquiry activities are better able to ask good questions regarding chemical phenomena and non-experimental chemistry learning experiences[58]. However, there are some criticisms of the instructional method such as: an over emphasises on the process of science to the detriment of scientific content, its cost to implement, takes more time and can be very difficult to manage especially with large cohorts. At undergraduate level, inquiry instruction is most commonly practiced during final year projects. However, Johnstone notes that it can be used earlier and encourages it to be occasionally used[15]. He suggests that an appropriate time to use inquiry instruction would be following an expository laboratory and indeed stipulates that inquiry should not occur in isolation, "*Real inquiry can only come after certain knowledge and facts and practical methods have been gained, these foundations can be laid down in an expository laboratory*"[15]. Additional examples of inquiry instruction are reported within the published literature[59,60].

In summary, four different instructional methods for use in the laboratory have been presented. In reality, many hybrids of these actually occur in practice[5]. Indeed this is the very reason Domin developed his taxonomy as he wanted to develop a framework that future research on the effects of different laboratory instructional methods could be based and compared[61]. It is clear from this review that there is no 'one fits all' instructional method for teaching laboratories as each has their own strengths and weaknesses. In effect the laboratory instructor/teacher needs to choose the instructional model based on the intended learning outcomes of an experimental task and that the overall learning outcomes be matched to the aims of laboratory work, thus throughout an entire module students will have the opportunity to maximise their learning experience. The aim of this work was to develop and implement a laboratory model for first year undergraduate chemistry students that would provide a suitable learning experience for students. The aims of the module are outlined in Section 3.2.

3.2 Laboratory module overview

In Section 3.1 an overview of reasons for and aims of laboratory work in undergraduate chemistry courses was presented. It was mentioned that the traditional, expository laboratory tends to dominate in undergraduate chemistry courses and though it does have its benefits, it does not completely satisfy the entire aims of laboratory work particularly in relation to developing professional skills and encouraging critical thinking. Following on from Garratt's aims of laboratory work (Table 3.2) and attempting to address calls from both employers and educators for improved skills sets amongst undergraduate students, a list of key elements to be included in a laboratory module was drawn up (Table 3.4). These key elements have been categorised under four overall aims of laboratories used in this study, namely to develop and provide experience of the following: (1) skills, (2) appropriate assessment, (3) positive learning environment and (4) knowledge and understanding (Table 3.4).

Table 3.4: List of 'aims' and corresponding 'key elements' to be included in the laboratory module introduced in this study

To develop and provide experience of the following:			
Skills	**Appropriate Assessment**	**Positive Learning Environment**	**Knowledge and Understanding**
▪ Technical ▪ Observation ▪ Communication ○ Oral Discussion ○ Presentations ○ Report Writing ▪ Recording ▪ Data Interpretation ▪ Data Manipulation ▪ Formulation of Experimental Process ▪ Laboratory Safety ▪ Team Work ▪ Problem Tasks	▪ Assessment of all laboratory work including skills ▪ Timely and appropriate feedback for student development and learning	▪ Develop confidence ▪ Develop independent learning and preparedness for laboratories ▪ Provide challenging activities ▪ Encourage motivation ▪ Provide an enjoyable experience ▪ Provide extensive academic and tutor support	▪ Improve underlying chemical knowledge ▪ Link between theory and practice

To achieve the four aims outlined and include the key elements identified in Table 3.4, seven specific actions were used in this laboratory module. These include a variety of experiments with specified learning outcomes, pre-laboratories tasks, maintained laboratory journal, student presentations, preparation of formal laboratory reports, variety of assessment formats and small group teaching. Each of these actions will be discussed in relation to their role in helping to achieve the key elements noted in Table 3.4.

3.2.1 Variety of experiments with specified learning outcomes

In this work it was deemed necessary and desirable to use a variety of different experiments to include some of the key elements listed in Table 3.4. In Table 3.5 an overall list of the experiments used in the module is given. A selection of these will be discussed to highlight how they were used to include some of the key elements listed in Table 3.4.

Table 3.5: List of experiments used in the laboratory module

Semester 1	Semester 2
1.1 Introduction to fundamentals in the lab	2.1 Det. of water hardness using EDTA titration
1.2 What is a mole?	2.2 Analysis of Rubex by back titration
1.3 Qualitative identification through solubility	2.3 Determination of dissociation constant of a weak acid
1.4 Identification of unknowns	2.4 Spectrophotometric determination of an equilibrium constant
1.5 Acids, bases, indicators and pH	2.5 Solid-liquid extraction of Trimyristin from nutmeg
Oral Presentation (1)	2.6 'Selgogg Abbey'
Practical Skills Assessment (1)	Oral Presentation (2)
1.6 What concentration is it?	Practical Skills Assessment (2)
1.7 Calorimetric determination of enthalpies	2.8 Dehydration of alcohol and isolation of it's products
1.8 Devise an experiment	2.10 Synthesis of Aspirin
1.9 Determination of the ideal gas constant	2.11 Hydrolysis of Trimyristin
1.10 Identification of the stoichiometry of a metal-ligand complex	2.12 Qualitative determination of functional groups

The first example is Exp 1.6 ‘What concentration is it?’. This experiment is mostly expository in nature in that students are given experimental instructions to follow to determine the concentration of an unknown acid solution by titrimetric analysis with a student prepared primary standard. This instruction method was chosen because the main outcomes of this experiment were to learn key technical skills (to demonstrate correct usage of related glassware, to accurately prepare a primary standard and to carry out an accurate titration). This experiment also gave students the opportunity to develop their data manipulation skills as titrimetric calculations were required to complete the experimental tasks. End-of-experiment questions were included which related to both technical and theoretical aspects of the experiment. These were incorporated to provide an additional challenge to students and help develop their underlying chemical knowledge.

The second example is Exp 1.3, ‘Qualitative Identification through solubility’. In this experiment students had to carry out a number of reactions and determine whether a reaction had occurred based on their observations and the solubility rules. The final task in the experiment required students to identify four unlabelled bottles using the knowledge and skills they have gained in the experiment. The key skills elements, from Table 3.4 which this experiment aimed to include were: observation, data interpretation, to provide challenging activities, encourage motivation, problem tasks, develop independent learning and improve underlying chemical knowledge. This experiment was task orientated, an abbreviated version of the tasks can be found in Figure 3.1. The task orientated structure was chosen for this experiment as it was intended that the completion of each task would give students confidence and motivation to tackle the later tasks. In addition, the knowledge and skills learned from each task were developmental, i.e. completion of later problem tasks required students to apply and practice skills learned in the earlier tasks. The third task involved students formulating and implementing their own experimental procedure to solve the given problem task.

In Exp 1.8 ‘Devise an Experiment’ students investigated the relationships between volume, temperature and pressure of a gas. They were required to formulate their own experimental procedures and to interpret their primary data. Students were only provided with the task outline: ‘*devise experiments in which you can obtain data to investigate the inter-*

relationships between volume, temperature and pressure of a gas'. This experiment was taken a laboratory module used in DCU previously[38].

Figure 3.1: Abbreviated task list of Exp 1.3 'Qualitative identification through solubility

Task 1 – Determining reactions

- React the following 7 compounds with each other. Your aim is to observe the reaction (if any) and then write the reaction (if any) showing the precipitate (if any). Also identify the solubility rule that describes the reaction.

  $NaOH$, KBr, KI, $FeSO_4$, $AgNO_3$, $BaCl_2$, Na_2CO_3

Task 2 – Testing for anions

- There are specific tests for anions which can be useful. Use a selection of the following compounds (in solution) to fill in the anion schemes, given below but first write the formula for each compound.
- Only carry out the appropriate tests on each compound e.g. carry out a sulfate test if you have copper (II) sulfate and a chloride test if you have zinc (II) chloride.

  Mercury (I) Nitrate, Mercury (II) Sulfate, Chromium (III) chloride, etc…x 8

Task 3 – Now the challenge

- You have been given four bottles containing HCl, $CuSO_4$, $AgNO_3$ and $BaCl_2$. However, the bottles are unlabelled.
- Your task is to label each solution properly. The catch is that you can only use these four solutions and you are only allowed to take 5mL, so you have to use your solutions wisely!
- Plan your procedure first and show it to your lab tutor. Then carry out your plan and identify the bottles.

The final example to show the 'variety of experiments' used in the laboratory module is Exp 2.6 'Selggog Abbey', which was a group, experimental problem task. It was implemented over a two week period after students had completed 15 laboratory sessions on inorganic and analytical chemistry.

The problem task centred on a three-river system in a fictitious region named Selggog Abbey. It involved groups of students (6-9), determining the water quality in the Selggog Abbey region on behalf of a fictional Environmental Protection Agency (EPA). Students were given some background information including details of industries and land use and were also provided with a map of the region and some recent reports of illegal polluting practices. Students were asked to (a) provide general information of the water quality, (b) identify and quantify any pollutants present and their possible sources (if any) and (c) to discuss the implications of their findings and to make appropriate recommendations. The problem involved both qualitative and quantitative analysis where students had to investigate the three sampling points highlighted in red on the map. The background information given directed the students to consider a variety of analyses including tests for water hardness, iron levels (both Fe^{2+} and Fe^{3+}), ascorbic acid, various cations and anions and sodium hypochlorite. Students would have encountered some of these tests previously in earlier laboratory tasks, but some were entirely new so in these cases, students were given detailed procedures for the analysis if requested.

Participation in the problem task gave students experience of working in teams and tackling 'pseudo real life' scenarios which attempted to illustrate the link between theory and practice. The completion of the problem required students to use technical and observations skills used previously, to interpret and manipulate data and to organise and formulate the experimental process they would use. It was hoped that the real life aspect of the problem would motivate students and that they would enjoy the challenge set. The problem task was also an opportunity for students to consolidate the underlying knowledge they had learned in the previous experiments.

These four examples are a snapshot of the variety of experiments used in the module. As mentioned previously the range of experiments were chosen to address the different key elements that this work tried to include in the laboratory module. In conjunction with the variety of experiments, specified learning outcomes for each experiment were highlighted in the laboratory manual. The inclusion of these had three main reasons. Firstly for the students, so they could see the purpose of each experiment and to have a check list with which they could use to self assess and determine if they had achieved what was expected of them. Secondly, they were included as a check list for the academic staff and tutors to help them focus on the key purposes of each experiment and thirdly to determine whether the objectives of the entire laboratory module satisfied all aspects of the laboratory elements outlined previously.

The learning outcomes were specific to each experiment and reflected the key focus of each laboratory task. In Table 3.6, some examples of learning outcomes are presented. These fall under two general headings, ‘knowledge’ and ‘skills’. The ‘knowledge’ learning outcomes ranged from lower order application (interconvert between grams, moles and molecules) to higher order evaluation (discuss implications of your findings and make appropriate recommendations). The ‘skills’ learning outcomes outlined specific psychomotor activities that students should be able to carry out such as operate a spectrophotometer.

Table 3.6: Sample examples of learning outcomes

At the end of this experiment you should be able to……
Knowledge (Cognitive)
▪ Write reaction equations
▪ Interconvert between grams, moles and molecules
▪ Devise a logical scheme to qualitatively test for unknown salts
▪ Plan an experiment to investigate the relationship between volume, temperature and pressure of a gas
▪ Solve practical problems using the ideal gas law
▪ Interpret graphical data to construct mathematical relationships between volume, temperature and pressure of a gas
▪ Discuss implications of your findings and make appropriate recommendations
Skills (Psychomotor)
▪ Prepare solutions of known concentrations
▪ Accurately record experimental data
▪ Accurately carry out a titration procedure
▪ Operate a spectrophotometer
▪ Carry out a solid-liquid extraction

3.2.2 Introduction of pre-laboratories tasks

The pre-laboratory tasks were included to help students 'to improve their underlying chemical knowledge' and 'to develop independent learning and preparedness for laboratories'. The use of pre-laboratories for this end is not new[62,63,64,65] and is supported by the information processing theoretical framework[66]. This model previously discussed in Chapter 1, emphasises the importance of both the perception filter and working memory and their interplay with the long term memory in student learning. From the model it was noted that a student has a limited working memory and, when this is overloaded, it has a negative influence on learning. Furthermore, it was discussed how information is stored in the long term memory and how this influences students' perception filter and as a result their ability to isolate signals from noise. Laboratories are places in which working memory space can be grossly overloaded[14]. Students have to cope with both written and verbal instructions, practicing manipulative skills, understanding concepts, finding equipment, safety concerns, disposal of chemicals, and making several observations and all within an allotted time frame. This can be an over-whelming experience. Pre-labs are used to help and encourage students to prepare for the laboratory so they don't experience a working memory overload. If this does occur student's resulting action is detrimental to their learning. "*In practice, to avoid overload, students can follow instructions blindly, resenting probing questions from demonstrators and maintaining their thinking brains in neutral*"[14]. Carnduff and Reid[1] suggest that private pre-laboratory work by the student might:

- Ensure that background information is recalled;
- Connect and revise prior knowledge;
- Provide some reassurance to the student about their grasp of the topic;
- Check that any procedures have been read and understood;
- Practice appropriate data handling, drawings or calculations;
- Lead the student into thinking about the procedures or concepts;
- Involve the student in planning;
- Connect the experiment with other parts of the course;
- Relate the experiment to the outside world;
- Improve motivation and perhaps, invite a prediction or offer a challenge.

Johnstone indicates that a pre-laboratory should not be a case of 'read your manual before hand' or 'do a few calculations'. He recommends that a pre-laboratory should include "revision of theory, re-acquaintance with skills, planning the experiment to some extent, discussion with members of a team about partition of labour and so on"[67]. In this work both Carnduff and Reid's suggestions and Johnstone's guidelines have been used as the backdrop for the development of the pre-laboratory tasks. It was intended that the tasks used would be lower order in nature and focus on basic understanding and terminology. Ultimately, the pre-laboratories had to be doable for the students, especially if they were to motivate them to engage with the laboratory task. Some examples of pre-laboratory tasks used are given in Table 3.7

Table 3.7: Examples of Pre-laboratory Tasks

- Write the symbols for the following anions – chloride, nitrate, sulfate, hydroxide, sulphide, carbonate, chromate, phosphate
- Find out the difference between a dilute solution and a concentrated solution
- Write out equations showing the dissociation of the following acid and base when dissolved in water: HCl and $Mg(OH)_2$
- What does the term anhydrous mean?
- Devise experiments in which you can obtain data to investigate the inter-relationships between the volume, the temperature and pressure of a gas
- Read through the entire experiment. In conjunction with the information and techniques you used in the previous experiment, devise a scheme to complete Task 3 in this weeks experiment. The scheme should be logical in identifying an unknown salt.
- If you were given a mixture of salt, benzoic acid, iron filings and pebbles how would you go about separating each of the above out from each other so you were left with each compound separately?

Additionally where relevant, students were given some calculation questions that reflected those that would be required during the laboratory session. In all of the experiments the task '*outline in your own words the purpose of this experiment'*, was used in the pre-laboratories. The purpose of this was to encourage students to identify what they would be doing in each experiment and write down their understanding of the experiment. It was hoped that by doing this students would read the entire experiment and thus be both more prepared and motivated to engage with the laboratories. In the problem experiment 'Selggog Abbey' previously discussed, students worked in groups. As part of the pre-laboratory preparation for the experiment students were required to elect a team leader, plan the experiment and distribute the work amongst the group.

3.2.3 Laboratory Journal

In Table 3.4, 'recording' is noted as a key skill that students should be given the opportunity to develop. Accurately recording of primary data is a key skill required for research and working in industry. The laboratory journal was introduced from the beginning as an essential component of the students' laboratory work. Students were given clear guidelines on what should be included and how the journal should be organised (see Figure 3.2). The journal was to be a true reflection and record of what students did *in the laboratory* containing observations, raw data, calculations, interpretation of data, graphical data, manipulation of data, answers to end of experiment questions etc. It was also to include students' preparation work for the laboratories i.e. their pre-laboratory tasks and experimental schemes when required.

Figure 3.2: Abbreviated Laboratory Journal guidelines

Your record of the experiment should be written up as the experiment is being carried out; also it should be brief and concise. It should contain enough information to trace a mistake or to allow someone else to carry out the experiment exactly as you did it.

For each experiment your notebook should contain the following:

- Experimental title and date
- Answer to pre-lab tasks
- Experimental aim/purpose – in your own words (2-3 sentences)
- Details of chemicals used including safety data, chemical equations, concentrations and amounts
- Brief experimental procedure/method
- Observations from experiment (colour changes, precipitates, experimental data etc…)
- All calculations (clearly laid out and explained)
- Results
- Discussion of what your experiment results mean – have you achieved your aim?
- Answer to any questions asked in the laboratory manual

Your notebook should have legible handwriting with neat and clearly laid out data. It need not be a work of art and there is no need to spend large amounts of time producing diagrams of equipment or drawings of apparatus. Also, as this notebook is to be used in the lab, it is inevitable that spills will occur.

As the journal contained details of students' preparation and in-laboratory work, it was one of the main sources used to assess students' work. Assessment in the laboratories will be discussed in more detail in Section 3.2.6.

3.2.4 Oral Presentations

In Table 3.4, communication skills are identified as important elements of a laboratory module. Making oral presentations is a probable feature of students' future employment whether they pursue a chemistry career or not. Communication skills are important transferable skills that should be developed within any undergraduate program. In this laboratory module students were required to give two short oral presentations (one in each semester) to develop the skill.

In the first semester, student were provided with presentation questions that were loosely based on laboratory content previously covered and were designed to be relatively easily solvable since the focus was on students giving a presentation not on catching them out on their chemistry knowledge. Students were given the presentation questions a short time (approx 30mins) prior to making their presentations. Three examples of questions used are given in Figure 3.3. In the second semester, students' presentations were based on the group problem task Selggog Abbey previously discussed in Section 3.2.1.

Figure 3.3: Examples of questions used in semester 1 oral presentations

1. Indigestion tablets are used to treat 'heart burn' by neutralising acid in the stomach. Often people use baking powder to do the same thing instead of indigestion tablets. Outline how you would determine which is more effective.

2. A 250ml sports drink contains glucose, 5% w/v. Another brand name sports drink contains 0.00125M glucose. Which drink would you recommend for a faster energy boost? (Glucose = $C_6H_{12}O_6$)

3. How would you explain to a non-scientific member of your family what a mole is in chemistry?

3.2.5 Formal Laboratory Reports

Writing formal laboratory reports is another key skill that students are required to learn during chemistry undergraduate courses. The ability to write a formal document is an important professional skill. Usually assessment of laboratories has been based on written laboratory reports. However, it was questioned whether assessment of laboratory reports was the only method of assessing student laboratory work and if in fact they were a suitable format to assess the totality of students laboratory work. Anecdotal evidence suggests that students have difficulties in writing laboratory reports in later years of degree programmes, even though, in a general first year science course they write many laboratory reports (approx 72 in DCU), as it is usually a requirement in biological and physical sciences too. In response to this it was decided to reduce the number of formal laboratory reports to three for the entirety of the module and increase their assessment weighting (the assessment weighting will be discussed more in Section 3.3.). The intention being that the increased assessment value would be an incentive to encourage students to focus more on the laboratory reports.

3.2.6 Variety of Assessment

Assessment is an essential component of the teaching and learning experience. In Chapter 1, both reasons for and formats of assessment have been discussed. It was also discussed how assessment influences students' approaches to learning and thus impacts the quality of learning. Additionally benefits of formative assessment and provision of feedback have been explored. In chemistry laboratories, the formal laboratory report is a common method of assessment; through this method, certain key elements including report writing, recording and data manipulation can be assessed. However, many key elements listed in Table 3.4 are not assessable using this format. In this work it was intended to include appropriate assessment that allowed for:

- Assessment of all elements of laboratory work;
- Timely and appropriate feedback for student development and learning

To achieve these intentions, various assessment formats were incorporated into the laboratory module. These included assessment of oral presentations, laboratory examinations, laboratory journals, pre-laboratories, skills and questioning and formal laboratory reports. The provision of timely feedback was an essential element of the assessment used in this module. Students received feedback for each assessment carried out in a timely manner, it was the intention that this would help promote a positive learning environment through development of student confidence and motivation and help to improve students' skills and underlying knowledge. The details, implementation and weighting of the assessment formats is discussed further in Section 3.3.2

3.2.7 Small group teaching – empowering the tutors

Thus far the key elements that this work intended to incorporate into a laboratory module and the actions through which these were to be realised have been outlined. The implementation of these with large cohorts of students is not an easy undertaking. There are many logistical difficulties such as assessment of students' laboratory skills and understanding, providing feedback and ensuring that all students receive appropriate support. In order to achieve all of these aims, the idea of small group teaching had to be integrated into the module. A reduction in the student-tutor ratio from 1:18 to 1:8 was facilitated to introduce this laboratory module. Through the use of small group teaching, the inclusion of the key elements listed in Table 3.4, were able to be tackled with a large cohort of students. In Section 3.4, brief implementation details regarding the module will be provided. These will detail the running of the laboratory and will discuss, tutor training and support, implementation of assessment formats and changes made between each semester.

3.3 Implementation

Introductory chemistry laboratories of a first year programme can be particularly difficult to set up and implement. Particular difficulties include large cohort sizes with varied interests and chemistry backgrounds. As mentioned previously, the advantage of expository laboratories is that they easier to manage which is one reason for their dominance at third level. In DCU these general difficulties are present and specifically include:

- Large numbers of students (typically 180-200 per year)
- Varied prior knowledge of chemistry (from very high marks in their final 2nd level examinations to no knowledge at all)
- Varied experience of practical work (from doing all 2nd level mandatory experiments to no exposure to practical work)
- Varied interest in chemistry (as the group combines students from 8 different undergraduate programmes)

As mentioned small group teaching was necessary to implement this module and attempt to achieve the aims that this work set out in Table 3.4. In Table 3.8 the tutor student ratio for this module implementation is given.

Table 3.8: Overview of student-tutor ratio for laboratory implementation

Semester	Students	Tutors	Tutors Groups	Ratio
1	180	15	15	1:12
2	180	20	24	1:7.5

3.3.1 Tutor Training and Support

Two days of training were provided to the tutors before the start of the module. The first training session explored the general role of tutors in laboratory and tutorial situations. Case studies were used to help tutors to understand what was expected of them and to learn how to deal with situations that arise when tutoring. Brief information sessions were provided by student learning supports units within the university e.g. counseling services. Finally, a workshop was provided examining communication skills with a specific emphasis on questioning and listening skills. The second training day focused on the implementation of the laboratory module. Students were presented with the overall rationale and reasons for the changes made to the laboratory module and the outcomes expected. They were given the specific details on their role in the implementation of the various aspects with specific attention being given towards the assessment system. It was also noted that the students were to be known as tutors and not demonstrators in order to reflect their changing role and importance in the laboratories.

Throughout the year, numerous meetings were held with tutors to gain feedback on their tutoring experiences and to clarify any implementation details where necessary including marking schemes. Tutors were provided with the opportunity to try out experiments prior to their tutoring session. In addition guidelines were provided for some of the experiments which included brief calculations and sample questions and answers to pre-labs, in-lab questioning and end of experiment questions.

3.3.2 Assessment Implementation

It was intended that through the variety of assessment methods students would be encouraged to participate and appreciate the importance of all aspects of the laboratory module. With this in mind weightings were assigned to the various assessment formats as given in Figure 3.4.

Figure 3.4: Overview of Laboratory Assessment

Overall Laboratory Assessment

%	Activity
60%	Laboratory
20%	Laboratory exams (2)
10%	Presentations (2)
10%	Laboratory reports

Marks	Activity
5	Pre-laboratory tasks
10	Pre-laboratory questioning
10	Skill mark
10	In-laboratory questioning
10	Laboratory journal

The laboratory activity accounted for 60% of the students overall mark. This grade was sub-divided into five sections, four of which are ‘in-lab’ based. All of the marking was carried out by the students’ assigned tutor during the laboratory session and students received feedback from the tutors.

The pre-laboratory task was given 15 marks which are further sub-divided into two sections, 5 marks for the pre-laboratory task and 10 marks for pre-laboratory questioning. Students were asked questions by the laboratory tutors at the beginning of each experiment and were awarded marks appropriately. Students were awarded a skill mark, this was an objective mark awarded by the tutor. It considered several factors including, manipulative skills, instrument operation, accuracy of results, and health and safety.

In-lab questioning was used to assess students understanding of the experiment being carried out. It was the intention that this would be done quite informally and that the questions would challenge and encourage students. The aim was to ask questions appropriate to the students’ chemistry ability and then gradually increase in difficulty to challenge and probe the students understanding.

The final part of the laboratory activity grade was that for the laboratory journal. Marks were awarded for completion of the journal in-line with the guidelines detailed in the laboratory manual. For example, marks were obtained for a journal which was clearly laid out and legible, had a logical sequence and had a record of all the work that the student completed including pre-laboratory, safety data, observations, calculations, results, interpretation of results and answers to questions asked in the lab manual.

It is noted that all of the laboratory marks were awarded by the tutor and contain elements of subjectivity. In order to maintain consistency, the academic in charge of the laboratory and the author randomly assessed different students and compared their marks with the tutors. Where discrepancies occurred, the mark would be discussed with the tutor in order to maintain as standard a marking system as possible.

Two laboratory exams were incorporated into the new laboratory module. One exam was held each semester. Each exam was worth 10% of the modules’ overall mark. Each exam had two parts, (a) theory and (b) practical. The intention was to assess both students’ knowledge and manipulative skills and to emphasise the importance of each.

The questions in the first exam specifically assessed knowledge of units, calculations, disposal of chemicals, selection of appropriate glassware, writing reaction equations, using solubility rules and interpretation of acid-base pH curves. Students were also required to demonstrate their ability to carry out basic laboratory and manipulative skills.

The second semester examination followed the same format as the first. In this exam some of the questions asked in first exam were re-asked but using different examples. Questions relating to units, calculations, separations, and interpretation of graphical data were used. Some more descriptive questions were also used:

1. Why would you heat some reactions under reflux while others can be heated in an open beaker?
2. You want to quantitatively extract lavender oil from a lavender plant 'Spike lavender (*L. latifoli*)'. Detail how you would do this, and note the reasons for each step taken.

Questions in the practical students involved students setting up reflux apparatus, preparing a vacuum filtration setup and recording a burette reading. Students completed a presentation and formal laboratory report in each of the semesters. These were assessed by the tutors. Presentation questions in the second semester were based on the problem task Selggog Abbey.

3.3.3 Implementation modifications

There were four main implementation changes introduced between the first and second semester. All of the changes introduced were carried out in response to feedback from students and tutors which will be discussed in Chapter 4.

1. Students in semester two started the experiments on their own without any interaction with the tutors
2. Tutors were given the option to collect student journals at end of a laboratory session to mark the journals outside of the laboratory
3. Students were allowed to complete the end of experiment questions outside of the scheduled laboratory time. (These had to be handed to the tutor before the next laboratory session so they could me graded)
4. Tutor weekly meetings were reduced to four meetings in the second semester.

In summary, between this chapter and Chapter 1, research literature relating to learning environments, motivation, student engagement, student learning, assessment and undergraduate chemistry laboratories have been discussed. Based on this framework a list of key elements to be introduced into a first year chemistry laboratory module has been presented. In addition, the actions to allow these to be implemented have been discussed. In Chapter 4, the methodology for the evaluation of the effectiveness of this laboratory module will be discussed in relation to skills, appropriate assessment, learning environment and knowledge and understanding. The findings and implications of the evaluation will also be given.

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Chapter 4:

Evaluation of Laboratory Implementation

In Chapter 3 a new laboratory module has been discussed that aimed to provide students with the opportunity to develop and gain experience of: (1) skills, (2) appropriate assessment, (3) a positive learning environment and (4) knowledge and understanding. This laboratory module was introduced in the phase 3 of this study. In Table 3.4 a list of key elements that this work intended to include in the laboratory module in order to achieve these four aims were given. Additionally, the rationale, implementation and actions used to include these elements were discussed. In this Chapter an evaluation of the laboratory module introduced is presented.

The findings obtained regarding the evaluation of the laboratory module will be discussed in three sections:

- Section 4.2: Evaluation of aims of the laboratory (*to provide students with the opportunity to develop and gain experience of skills, appropriate assessment, positive learning environment, knowledge and understanding),* based on student and tutor opinion;

- Section 4.3: Evaluation of: (1) tutor training and support, and (2) the implementation of the assessment structures.

- Section 4.4: Evaluation of student performance in the various assessment elements.

4.1 Evaluation Methodology

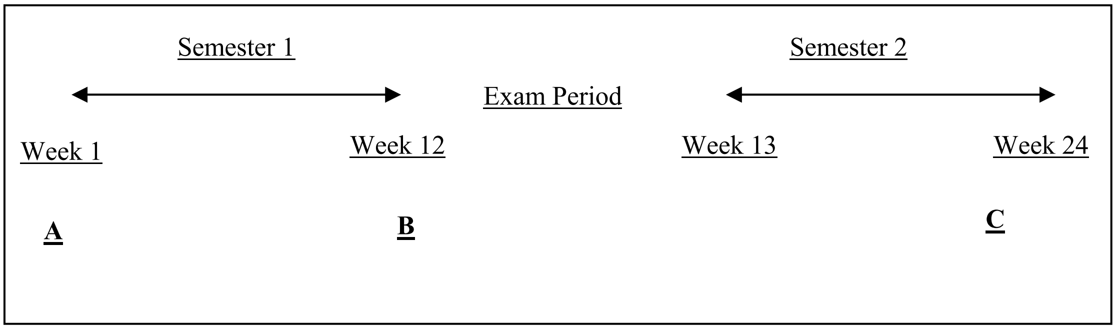
In Table 4.1 an overview of the aims and corresponding key elements included in this module are given. Additionally, the actions introduced to achieve these aims, and the evaluation tools used to determine the success of the laboratory implementation, is outlined. As indicated in column three of Table 4.1, student and tutor opinions were primarily obtained using surveys, and through some small group interviews. The surveys used were designed to evaluate the extent to which the aims of the laboratory module were achieved. The skills survey used was adapted from a Royal Society of Chemistry's 'Undergraduate Skills Record (USR)[1]. In Figure 4.1, a timeline of the data collection is presented and the response rate is given. Copies of all surveys used can be found in the Appendix.

Table 4.1: Overview of evaluation tools used to determine if, the aims and corresponding key elements were successfully introduced in this laboratory module.

Aims and corresponding key elements introduced into the laboratory module	**Actions used to incorporate key elements into the laboratory**	**Evaluation Tools**
1. Skills		
Technical	Variety of experiments Variety of assessment	Lab exams Skill mark Student survey Tutor survey
Observations	Variety of experiments Variety of assessment	Exam Laboratory journal Student survey
Communication		
Oral discussion	Small group teaching Variety of assessment	Not directly evaluated
Presentation	Two presentations Variety of assessment Small group teaching	Presentation grade Student survey Tutor survey
Report writing	Three formal lab reports Variety of assessment	Report grade Student survey
Recording	Laboratory journal Variety of assessment	Laboratory journal Student survey Report grade
Data interpretation	Variety of experiments	Exam Laboratory journal Report grade Student survey
Data manipulation	Variety of experiments	Exam Report grade Laboratory journal Student survey
Formulation of experimental process	Variety of experiments	Student survey Exam
Laboratory safety	Small group teaching	Student survey
Team work	Variety of experiments	Not directly evaluated
Problem tasks	Variety of experiments	Student survey

2. Appropriate Assessment		
Assessment of all laboratory work including skills	Variety of assessment Small group teaching Laboratory journal	Exams Presentations In-lab assessment Student Survey Tutor Survey
Timely and appropriate feedback for student development and learning	Variety of assessment Small group teaching	Student Survey Tutor Survey
3. Positive Learning Environment to…		
Develop confidence	Small group teaching	Student survey Tutor survey
Develop independent learning and preparedness for laboratories	Variety of experiments Pre-laboratories Variety of assessment	Student survey Tutor survey Pre-lab grades
Provide challenging activities	Variety of experiments Variety of assessment	Student survey Tutor survey
Encourage motivation	Variety of experiments Small group teaching Variety of assessment	Student survey Tutor survey
Provide an enjoyable experience	Variety of experiments Small group teaching	Student survey Tutor survey
Provide extensive academic and tutor support	Small group teaching	Student survey Tutor survey
4.Knowldge and Understanding		
Improve underlying chemical knowledge	Small group teaching Variety of experiments Variety of assessment Pre-laboratories	Student survey Tutor survey Assessment
Link between theory and practice	Small group teaching Variety of experiments	Student survey Some aspects not directly evaluated

Figure 4.1: Timeline of data collection for laboratory evaluation (Phase 3)



Time	Evaluation	N	Gender[†]		Leaving Certificate[†]	
			Male	Female	PC	NC
A	Skills Survey[♠]	162	67	95	72	87
B	Lab Evaluation (1)	150	64	86	74	70
	Tutor Survey (1)	14	7	7	-	-
	Tutor Interview (1)	12	7	5	-	-
C	Lab Evaluation (2)[♦]	145	57	83	65	69
	Tutor Survey (2)	15	5	10	-	-
	Tutor Interview (2)	15	5	10	-	-

[†]Not all students completed all identifiers thus information could not be determined
[♠]Skills survey was a component of the MPE survey discussed in Chapter 1
[♦]A repeat of the Skills survey was included in this evaluation

4.2 Evaluation of aims of the laboratory based on student and tutor opinion

4.2.1 Skills

In Table 4.2 the key ‘skill’ elements which the skills survey evaluated are highlighted. It is noted that some of the skill elements, namely team work, problem tasks, and report writing are not directly evaluated using this survey. These will be discussed in further detail throughout this chapter.

As noted in Figure 4.1, students indicated their level confidence in relation to the skill elements at the beginning of the academic year. They were mostly confident in their abilities to carry out the various skills. In Table 4.3, student responses are provided.

Table 4.2: Outline of statements from the 'skills survey' and the corresponding key elements that were used to evaluate

Skills Survey Statements	Key Elements
I am able to handle chemicals in the laboratory	Technical
I am able to handle glassware in the laboratory	Technical
I am aware of specific hazards relating to chemicals	Laboratory safety
I am able to measure and observe chemical events and changes	Observation
I am able to analyse and evaluate experimental data	Data manipulation Data interpretation
I am able to interpret chemical information	Data interpretation
I am able to select appropriate techniques and procedure	Formulation of experimental process
I can identify errors in chemistry experiments	Data interpretation Formulation of experimental process
I am able to maintain good laboratory notes	Recording
I am confident in planning and making oral presentations	Communication♦

♦This question was asked in a different survey and was not specifically asked in relation to chemistry laboratories

Students appear to be most confident in terms of recording, laboratory safety, observation and technical skills; more that 69% of students agreed with the statements in the survey relating to these skills. Students were less confident regarding their data interpretation, data manipulation and formulation of experimental skills. The mean score for statements relating to these skills were 3.50, 3.47 and 3.55 respectively, with ~44% of students indicated a response of 'somewhat/not sure' to all of these attributes. Students were least confident regarding planning and making oral presentations.

Gender difference appears to have little impact of students' confidence in relation to these skills. Recording and communication are the only two in which there is a significant difference between the gender groups. Female students were more confident in their ability to maintain laboratory notes (p = 0.004) and less confidence in making oral presentations (p = 0.001).

Table 4.3: Percentage level of student agreement to statements regarding 'skills confidence'

Statement	N	Very Strongly / Strongly agree	Somewhat /not sure	Very Weakly / Weakly agree	Mean
I am able to **handle chemicals** in the laboratory	155	74	25	1	4.02
I am able to **handle glassware** in the laboratory	155	90	9	1	4.33
I am **aware of** specific **hazards** relating to chemicals	154	84	14	2	4.15
I am able to **measure and observe** chemical events and changes	155	69	27	4	3.92
I am able to **analyse and evaluate** experimental data	155	65	31	4	3.88
I am able to **interpret** chemical information	154	46	44	10	3.50
I am able to **select appropriate techniques and procedure**	155	48	44	8	3.55
I can **identify errors** in chemistry experiments	154	45	45	10	3.47
I am able to **maintain good laboratory notes**	155	81	15	4	4.05
I am confident in **planning and making** oral presentations	157	22	36	32	3.03

Perhaps to be expected students previous chemistry experience did influence students' confidence in relation to these skills at the start of the year. In Table 4.4, independent *t-test* results highlight the difference between the two groups of students. PC students indicate a higher confidence level regarding technical skills, data manipulation, data interpretation, observation and formulation of experimental process. There is no significant difference regarding laboratory safety, recording and communication skills. Perhaps most interesting is that students score a similar level of confidence in their ability to analyse and evaluate experimental data. This could perhaps indicate that this skill along with laboratory safety, recording and communication skills are not seen by students as subject specific.

Table 4.4: Differences in students' confidence levels regarding 'skills' on entry to university, based on previous chemistry experience.

Statement	PC		NC		*t*	*df*	*p*
	Mean	*σ*	Mean	*σ*			
I am able to **handle chemicals** in the laboratory	4.33	0.70	3.76	0.74	4.86	151	0.000*
I am able to **handle glassware** in the laboratory	4.47	0.68	4.20	0.69	2.40	151	0.018*
I am aware of **specific hazards** relating to chemicals	4.26	0.72	4.04	0.73	1.88	150	0.063
I am able to **measure and observe** chemical events and changes	4.20	0.79	3.65	0.77	4.34	151	0.000*
I am able to **analyse and evaluate** experimental data	3.93	0.92	3.82	0.78	0.79	151	0.429
I am able to **interpret** chemical information	3.77	0.86	3.25	0.76	3.91	150	0.000*
I am able to **select appropriate techniques and procedure**	3.76	0.86	3.36	0.79	2.97	151	0.004*
I **can identify errors** in chemistry experiments	3.78	0.92	3.19	0.76	4.36	150	0.000*
I am able to **maintain good laboratory notes**	4.07	0.87	4.02	0.81	0.35	151	0.729
I am confident in **planning and making** oral presentations	3.01	1.21	3.00	1.06	0.09	153	0.938

Having completed the laboratory module, students felt that they learned laboratory skills through the laboratories, and they mostly agreed that the problem task 'Selggog Abbey' allowed them to use the skills they had previously learned (see Table 4.5). They also indicate a general confidence in their skills abilities. They are most confident regarding their technical skills, laboratory safety and observation skills. The lowest mean score of this grouping is 4.27. Between 83% and 99% of students indicated an agreement with the statements regarding these skills. Planning and making oral presentations is the skill which students noted they were least confident in. 53% were confident making oral presentations and 38% indicated they were not with the remainder undecided. The majority of students indicated reasonable levels of confidence in terms of data manipulation and data interpretation. They agreed with both the statements, 'I am able to analyse and evaluate experimental data' (mean = 4.27) and 'I am able to interpret chemical information' (mean = 4.06). Though still positive, students responses point towards a lesser confidence in their abilities to formulate experimental processes, 11% and 16% of students disagreed with the statements, 'I am able to select appropriate techniques and procedures' and 'I can identify errors in chemistry experiments' respectively.

Similarly to the first semester, gender difference does not appear to have a large influence regarding students' skills abilities. The same trends relating to maintaining laboratory notes and making oral presentations are found where females were significantly more confident to the first than their male colleagues (p = 0.042) and lesser on the latter (p = 0.005). In addition, female students were significantly less confident in their ability to 'interpret chemical information' than the male students (p = 0.032), though their overall confidence level towards this skill was quite positive (mean = 3.71).

PC and NC students were mostly positive towards their confidence in the various skills. However, there was still a significant different level indicated between the two groups at the end of the year. PC students showed a higher level of confidence towards half of the skill statements compared to NC students (see Table 4.6). The differences related to technical skills, observation, data manipulation, data interpretation and formulation of experimental process. PC students were more confident when handling chemicals, observing chemical changes, analysing and evaluating experimental data, interpreting chemical information and selecting appropriate techniques and procedures. The latter two are of most concern as NC students indicated 3.54 and 3.51 mean scores respectively on the statements relating to these skills. As noted at the start of the year, there was still no difference regarding recording skills, laboratory safety and communication skills.

Table 4.5: Students' opinions of learning 'skills', and their skills confidence, at the end of the laboratory module (% agreement)

Statement	N	Very Strongly/ Strongly agree	Somewhat /not sure	Very Weakly / Weakly agree	Mean
I **learned lab skills** in the chemistry laboratories	138	94	5	1	4.43
The water problem 'Selgogg Abbey' **allowed me to use skills** I learned during 1st and 2nd semester	144	94	4	2	4.41
I am able to **handle chemicals** in the laboratory	135	94	4	2	4.46
I am able to **handle glassware** in the laboratory	135	99	1		4.62
I am **aware of specific hazards** relating to chemicals	135	89	7	4	4.36
I am able to **measure and observe** chemical events and changes	135	83	16	1	4.27
I am able to **analyse and evaluate** experimental data	135	73	22	5	4.06
I am able to **interpret** chemical information	135	65	28	7	3.84
I am able to **select appropriate techniques and procedure**	135	60	29	11	3.71
I can **identify errors** in chemistry experiments	135	53	31	16	3.56
I am able to **maintain good laboratory notes**	135	66	27	7	3.86
I am confident in **planning and making oral presentations**	139	52	14	34	3.23

Table 4.6: Differences in students' skills confidence at the end of the laboratory module, considering students' previous chemistry experience

Statement	PC		NC		*t*	*df*	*p*
	Mean	*σ*	Mean	*σ*			
I am able to **handle chemicals** in the laboratory	4.62	0.63	4.32	0.73	2.25	109	0.020*
I am able to **handle glassware** in the laboratory	4.69	0.47	4.56	0.53	1.40	109	0.164
I am **aware of** specific **hazards** relating to chemicals	4.40	0.85	4.31	0.73	0.66	109	0.509
I am able to **measure and observe** chemical events and changes	4.48	0.67	4.15	0.78	2.35	109	0.020*
I am able to **analyse and evaluate** experimental data	4.31	0.85	3.90	0.87	2.51	109	0.014*
I am able to **interpret** chemical information	4.15	0.85	3.54	0.90	3.68	109	0.000*
I am able to **select appropriate techniques and procedure**	4.06	0.80	3.51	1.02	3.16	108	0.002*
I can **identify errors** in chemistry experiments	3.77	1.10	3.41	1.04	1.79	109	0.076
I am able to **maintain good laboratory notes**	3.87	1.09	3.86	0.88	0.01	109	0.996
I am confident in **planning and making oral presentations**	3.18	1.28	3.26	1.13	0.38	131	0.708

At the end of the laboratory module it is clear that there was an overall increase in students' confidence in their 'skills abilities' compared to their initial levels indicated on entry to university (see Table 4.7). There were significant increases observed regarding technical skills, laboratory safety, observation and ability to interpret chemical information. There were no significant changes noted for students' confidence in data manipulation, recording or communication skills. In Section 5.4 students' performance in the various skills elements will be discussed.

A key focus of this work was that students would gain experience of, and would develop key skills (Table 4.1). From this analysis it is evident that students' levels of confidence in their ability to carry out specific skills is quite positive and has generally increased from their initial levels. An average mean score of 4.0 was recorded for the skills statements. Students were most confident in their technical, laboratory safety and observation skills and least confident in their communication skills. It is shown that there is a gender bias when recording and communication skills are investigated where female students are more confident in there recording abilities and less in their communication skills compared to their male colleagues. Indeed overall student confidence in making oral presentations is low. At the end of the module, there are still significant differences observed when previous chemistry experience is considered. PC students are generally more confident than NC students for most skills.

Table 4.7: Changes in skills confidence from entry to university to the end of year one

Statement	MPE		LE_2		*t*	*df*	*p*
	Mean	σ	Mean	σ			
I am able to **handle chemicals** in the laboratory	4.06	0.78	4.45	0.68	5.20	112	0.000*
I am able to **handle glassware** in the laboratory	4.33	0.69	4.64	0.50	4.49	112	0.000*
I am **aware of specific hazards** relating to chemicals	4.16	0.75	4.40	0.72	3.11	111	0.002*
I am able to **measure and observe** chemical events and changes	3.94	0.83	4.27	0.76	3.92	112	0.000*
I am able to **analyse and evaluate** experimental data	3.90	0.83	4.06	0.85	1.62	112	0.109
I am able to **interpret** chemical information	3.52	0.87	3.83	0.92	3.45	111	0.001*
I am able to **select appropriate techniques and procedure**	3.57	0.85	3.77	0.95	1.91	112	0.059
I can **identify errors** in chemistry experiments	3.60	0.88	3.58	1.04	0.16	111	0.871
I am able to **maintain good laboratory notes**	4.07	0.87	3.88	1.01	1.93	112	0.056
I am confident in planning and making **oral presentations**	3.08	1.15	3.25	1.22	1.80	121	0.075

MPE = Survey in which first skills survey was carried out at the start of year one
LE_2 = Laboratory evaluation survey carried out in at the end of year one

4.2.2 Appropriate Assessment

The rationale for introducing a variety of assessment into the laboratory module has previously been discussed in detail in Chapter 3. The intention was to introduce assessment formats that would encourage student engagement and provide timely and appropriate feedback to students in order to best help them develop skills, knowledge and understanding.

At the end of the year, students provided their opinions regarding the various assessment formats used (Tables 4.8 and 4.9). The majority of students liked the assessments, there was a 69% average approval rating which ranged from 56% for tutor questioning to 79% for laboratory reports. Students preferred laboratory reports, laboratory journals and the pre-laboratories. Oral presentations and tutor questioning were highlighted as those which they least liked. Female students liked these two assessment formats significantly less than their male colleagues ($p = 0.003$ and $p = 0.013$, respectively). However, they preferred the laboratory journal more than male students ($p = 0.000$). These findings reflect students levels of confidence in communication and recording skills discussed in Section 4.2.1. PC students held a stronger preference for examinations ($p = 0.025$) and laboratory reports ($p = 0.016$) compared to NC students.

Table 4.8: Students' opinion of the assessment formats used in the laboratory module (% agreement)

I liked the assessment method	N	Very strongly / Strongly agree	Somewhat /not sure	Very weakly /weakly agree	Mean
Tutor questioning	144	56	18	26	3.41
Prelab	144	73	15	12	3.82
Laboratory journal	144	77	13	10	3.90
Exam	143	67	17	16	3.67
Oral presentation	144	63	16	21	3.63
Laboratory reports	144	79	9	12	3.94

Students were more favourable towards the different assessment formats when asked whether they 'allowed them to demonstrate their abilities'. They were positive towards all of the formats with laboratory reports identified as the one which they felt best allowed them to demonstrate their abilities (mean = 4.13). This was closely followed by examination (mean = 3.95), laboratory journal (mean = 3.94) and pre-laboratories (mean = 3.90). Oral presentations were identified as the least favourable format with 66% agreeing to the statement indicated in Table 4.9. Male and female students disagreed regarding their preference towards tutor questioning and the oral presentations. Male students held a higher regard for each of these formats ($p = 0.013$ and $p = 0.003$ respectively). The finding reflects earlier analysis which showed female students were less confident making oral presentation. Tutors noted that the examination and presentations were good assessment formats that provided good learning opportunities for the students. One tutor commented on the examinations, *"students got everything done and they knew by the end of the end of it what they should know and what they should be able to do, such as understanding things, and what lab skills they should be able to do"*.

Table 4.9: Students' opinions of the assessment formats in terms of the opportunity to 'demonstrate their abilities' (% agreement)

I feel the assessment method allowed me to demonstrate my 'abilities':	N	Very strongly / Strongly	Somewhat /not sure	Very weakly / weakly	Mean
Tutor questioning	144	72	16	12	3.83
Prelab	144	78	13	9	3.90
Laboratory journal	144	79	15	6	3.94
Exam	144	74	21	5	3.95
Oral presentation	144	66	19	15	3.77
Laboratory reports	144	83	11	6	4.13

At the end of the first semester, the majority of tutors (57%) indicated that students responded positively to the questioning element of the assessment formats though some where not in full agreement with this (Table 4.10). The majority (64%) also felt that students received justified rewards for the work they had put into the laboratories, though

29% were uncertain and 7% disagreed. Unfortunately however, it is not clear whether these tutors believed that the students received more or less marks than they deserved.

Table 4.10: Tutors' opinions regarding students' interaction with questioning at the end of semester one (% agreement)

Statement	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
Students responded positively to questioning within the lab	14	57	43	0	3.57
Students were fairly rewarded for the work they put in	14	64	29	7	3.71

Students were somewhat more positive towards tutor questioning (Table 4.11). 82% indicated that the questioning made them think about the chemistry they were doing and 74% noted the questioning made them more confident and clearer about the chemistry being covered. 75% of students also note that the questioning on the pre-laboratories encouraged them to do better in subsequent pre-laboratories. Students were slightly less positive between the correlation of the marks they obtained and the effort that they applied. 35% of students were unsure whether these matched up and 10% didn't think they correlated. As with the tutors, it is unfortunately not clear whether they believed they deserved more or less marks. There were variation in students opinions towards the assessment formats when gender and previous chemistry experience was considered.

At the end of the second semester, tutors were slightly less positive towards students' response to questioning in the laboratory. A similar majority indicated that students were positive towards the questioning; however 13% did not believe this to be the situation (Table 4.12). One tutor commented, '*Sometimes students were not responsive and they didn't want to learn which is frustrating when you are trying to give them your time but I guess that is teaching*'. Tutors expressed similar opinions to the first semester regarding correlations between student effort and marks they were given.

Table 4.11: Students' opinion towards tutor questioning at the end of semester one (% agreement)

Statement	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
Tutor questioning on the pre-lab encouraged me to do my best in subsequent pre-labs	147	75	17	8	3.81
My marks in the pre-lab reflected the effort I put into them.	136	55	35	10	3.60
The tutors questions made me think about the chemistry I was doing	150	82	12	6	4.13
Answering tutor questions made me confident/clearer about the chemistry I was doing	149	74	16	10	3.92

Table 4.12: Tutors' opinions of student interaction with questioning at the end of semester two (% agreement)

Statement	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
Students responded positively to questioning within the lab	15	53	34	13	3.40
Students were fairly rewarded for the work they out in	15	73	20	7	3.80

There was little change noted at the end of the second semester regarding students' opinion of the questioning used for assessment (Table 4.13). Students were reasonably positive towards the use of questioning and the majority indicated that the questioning made them think about the chemistry (82%) and made them confident and clearer about the chemistry (75%). There was a significant increase in student opinion regarding the effort-marks rewarded correlation ($p = 0.007$). At the end of the second semester, students significantly agreed more than previously with the statement relating to correlation between marks and effort (mean = 3.81). The majority of students believed that the feedback received from tutors regarding both their performance in the laboratories (56%) and their understanding (58%) was appropriate. However, 24% and 22% respectively, of students did not agree with this point. These figures are disappointing considering student feedback is seen as an important component of the assessment used in this laboratory. It is suggested that this is an area which needs further investigation in the future. Gender differences do appear to have had some influence on student opinion regarding questioning in the second semester. Male students were significantly more positive towards questioning making them think ($p = 0.012$) and being more confident and clearer ($p = 0.024$) about the chemistry being covered. As in the first semester no significant difference was observed when previous chemistry was considered.

In summary, students generally liked the assessment formats used and they felt that they allowed them to demonstrate their abilities. Laboratory reports and the laboratory journal were most liked by the students and they also indicated a high preference towards these formats in addition to the pre-laboratories and the examinations in terms of allowing them demonstrate their abilities. Tutor questioning is the format least liked by students though the majority indicated this assessment allowed them to demonstrate their abilities. Indeed after both semesters students indicated the tutor questioning encouraged them to do better in subsequent pre-laboratories, made them think about the chemistry and made them more confident and clearer about the chemistry. The gender difference in student confidence regarding recording and communication skills reflects students' preference of assessment format. Male students appear to have a greater affinity towards questioning and oral presentations compared to their female colleagues who in turn favour the laboratory journal more than then male students. Students' previous chemistry experience seems to have had no influence on students' preference and interaction with the various assessment formats used in the module. One point of concern that needs to be further investigated and addressed is that approximately one fifth of students did not feel the feedback they received from the tutors was appropriate regarding their performance and understanding.

Table 4.13: Students' opinions of tutor questioning at the end of semester two (% agreement)

Statement	N	Very strongly / strongly	Somewhat /not sure	Very weakly / weakly	Mean
Tutor questioning on the pre-lab encouraged me to do my best in subsequent pre-labs	144	69	16	15	3.72
My marks in the pre-lab reflected the effort I put into them.	135	67	22	11	3.81
The tutors questions made me think about the chemistry I was doing	143	82	10	8	4.16
Answering tutor questions made me confident/clearer about the chemistry I was doing	143	75	13	12	3.95
I received appropriate feedback from my tutor regarding my performance in laboratories	143	56	20	24	3.42
I received appropriate feedback from my tutor regarding my understanding in laboratories	144	58	20	22	3.47

4.2.3 Positive Learning Environment

In Table 3.4, a list of key elements to be achieved under the heading of 'Positive Learning Environment' where identified. These include, to:

- Develop confidence
- Promote independent learning and preparedness for laboratories
- Provide challenging activities
- Encourage motivation

- Provide an enjoyable experience
- Provide extensive academic and tutor support

Various actions including small group teaching and variety of assessment were intended to contribute to achieving the learning environment; indeed it has already been reported in Section 4.2.2 that tutor questioning on pre-laboratories encouraged students to think and do better in subsequent pre-laboratories. In this section, some more detailed evaluation regarding these key elements will be discussed in three sections, (1) enjoyment, motivation and confidence, (2) preparedness, laboratory challenge and independent learning and (3) tutor and academic support.

(1) Enjoyment, motivation and confidence

Student feedback on their first semester laboratory experience (Time B – Figure 4.1), indicated some mixed opinions regarding their level of enjoyment. 47% indicated they liked/enjoyed the laboratories where 25% gave the opposite view. There were no difference in opinions expressed when gender was considered. PC students enjoyed/liked the labs significantly more than NC students (p = 0.012). Students' views were reflected by tutor feedback which was largely uncertain about students' enjoyment of the laboratories (mean = 3.21) (Table 4.14)**.** Though not fully representative of the entire cohort, some qualitative feedback received indicated that students most enjoyed, 'doing experiments', 'doing things on their own', 'using different equipment and chemicals' and 'achieving results that made sense'. 'Feeling rushed', 'feeling overwhelmed', 'not being shown how to do the experiments', 'the opening weeks were stressful' and 'being afraid of breaking glassware' were identified as some issues that students particularly disliked in the first semester. The 'stress' indicated in some of the comments is perhaps explained by students response to the statement, 'If I prepared properly for the lab, there was enough time to complete the lab'. Only 29% of students felt that this was the situation. It appears that students didn't think they had enough time within the laboratory to complete the work.

In the first semester some experiments were structured in tasks to make them more accessible to students and ultimately encourage them to engage with the laboratories. It was hoped that the tasks would help students to scaffold their learning so they would be able to build on each part. 65% of students indicated that the task system did prepare them to be able to complete the final problem task (Table 4.15). 45% of students felt that the task structure encouraged them to complete the entire laboratory experiment; however 29% noted that it did not motivate them to the same extent. However, tutors (64%) did highlight that student general effort towards the laboratories increased as the first semester progressed.

Table 4.14: Students' and tutors' views of student enjoyment of the laboratories at the end of semester one (% agreement)

		N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
Students	I enjoyed/liked the chemistry labs	150	47	28	25	3.29
	If I prepared properly for the lab there was enough time to complete the lab experiments	148	29	29	42	2.80
Tutors	Students enjoyed the laboratory experience	14	29	57	14	3.21

Table 4.15: Student' opinions of task structure and tutors' opinion of student applied effort at the end of semester one (% agreement)

	Statement	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
Student	Having a no. of different tasks to complete within the lab encouraged me to complete the entire lab	149	45	26	29	3.19
	The initial tasks (tasks 1-2) prepared me to complete the problem tasks (task 3) at the end of the experiment	149	65	21	14	3.63
Tutor	Students general effort increased as the semester progressed	14	64	22	14	3.71

At the end of the second semester both tutor and student feedback indicated improved enjoyment, motivation, and student confidence compared to the end of the first semester. In Table 4.16, it is shown that there was a significant increase in student enjoyment of the laboratories. Time pressures were again mentioned by some students as an issue at the end of the second semester. Some students (37%) still felt that they could not finish the experiments even if they had prepared properly. The responses to the qualitative questions noted that students tended to like group work and they felt that the experiments in the second semester were more interesting and challenging which encouraged them to think. Some students highlighted the group laboratory report as something which they didn't like and which caused undue stress. Some also highlighted frustration regarding not having enough equipment in their lockers and wasting time looking for it. In addition they felt they were overcrowded in the fumehoods, a sentiment echoed by the tutors.

Table 4.16: Change in students' enjoyment of the laboratories from end of semester one to end of semester two

Statement	LE_1		LE_2		*t*	*df*	*p*
	Mean	***σ***	**Mean**	***σ***			
I enjoyed/liked the chemistry labs	3.44	1.14	3.83	1.09	3.52	111	0.001*

LE_1 = Laboratory evaluation carried out at the end of semester one
LE_2 = Laboratory evaluation carried out at the end of semester two

70% of students have pointed out they became more motivated in the 2nd semester laboratories and 84% that they felt more confident (Table 4.17). These findings are supported by tutors' responses; 64% thought students enjoyed the 2nd semester laboratory and 67% indicated that their students were more motivated in the 2nd semester. 89% highlighted that students became more confident compared to semester 1 and 87% felt that students were more confident as the second semester progressed (Table 4.18). One tutor said that, '*my students enjoyed the labs and their confidence improved throughout and their lab skills improved and they were no longer shy*'. Tutors also appeared to enjoy the experience too. Only two of the tutors didn't like tutoring, one felt it took up too much of her research time and the other felt that laboratories should only be used to teach skills, thus the questioning etc was a distraction to students. Those that did enjoy the laboratories indicated a few reasons. One tutor commented, '*it was a good opportunity to develop our personal skills and to become creative and develop different approaches to help students, i.e. different ways of explaining things'* another said that *'it was nice to have an introduction to teaching, since it could be a viable career and I saw what it* [teaching] *was not daunting'*. Other tutors mentioned that they improved their own understanding of basic chemistry by having to teach it but overall tutor most enjoyed their interaction with the students.

Table 4.17: Students' opinions of their experience in the laboratory module, at the end of year two (% agreement)

Statement	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
I became more motivated in 2nd semester labs	144	70	17	13	3.80
I felt more confident in the laboratory in the 2nd semester	144	84	10	6	4.13

Table 4.18: Tutors' opinions of students' interaction during the second semester (% agreement)

Statement	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
Students enjoyed the laboratory experience	14	64	29	7	3.71
My students motivation increased as the semester progressed	15	60	13	27	3.53
My students were more motivated in semester two	9	67	33	0	3.89
My students were more confident as the semester progressed	15	87	13	0	4.20
My students were more confident in the 2nd semester	9	89	11	0	4.22

(2) Student preparedness, laboratory challenge and independent learning

Tutors held mixed opinions regarding student application towards doing 1st semester pre-laboratories and understanding them. Only 36% of tutors felt that students applied a lot of effort towards the pre-laboratories and only 38% believed students put efforts towards understanding these pre-laboratories (Table 4.19).

Table 4.19: Tutors' opinion of students interaction with pre-laboratories during semester one (% agreement)

	N	Very strongly/ strongly	Somewhat /not sure	Very weakly / weakly	Mean
Students put a lot of effort into the pre-labs	14	36	43	21	3.00
Students put effort into understanding the pre-labs	14	38	39	23	3.15

This feedback perhaps somewhat explains student feedback regarding the pre-laboratory tasks (Table 4.20) where between 49% and 52% of students felt that after completing the pre-laboratories they were more confident they understood the theory and practical aspects they would encounter in the laboratory. Similarly 53% of students felt they were well prepared for the laboratories each week. There appears to be a group of 20% of students who felt unconfident towards the chemistry and practical work and overall felt unprepared for the laboratories. However, 83% of students indicated that they were aware of the aim of the experiments. This may be a sign of students using the learning outcomes to determine what is expected of them and that perhaps it was beneficial for them to outline that aims of each experiment in their own words as part of the pre-laboratory tasks.

There appears to be no gender difference when laboratory preparation was investigated; however, it is clearly evident that NC students were less confident about their understanding of the theory and practical work being covered; they generally felt less prepared than PC students (Table 4.21). Based on tutor feedback, some students lack of confidence may have been due to perceived lack of applied effort however it could also be the situation that the content of the pre-laboratories needs to be examined further to ensure they satisfy the aims previously outlined in Chapter 3 such as providing reassurance to students about their grasp of the topic knowledge and encouraging independent study and preparedness for the laboratories.

Table 4.20: Students' opinion of pre-laboratories during semester one (% agreement)

Statement	**N**	**Very strongly / strongly agree**	**Somewhat /not sure**	**Very weakly / weakly agree**	**Mean**
Having completed the pre-lab I was confident I understood the chemistry theory relating to the related laboratories	150	49	31	20	3.33
Having completed the pre-lab I was confident about the practical work I would complete in the laboratory	150	52	29	19	3.38
I was well prepared for the experiment that I would carry out each week	149	43	29	18	3.41
I was aware of the aim of the experiment before I entered the lab	149	83	9	8	4.04

Table 4.21: Difference in student opinion of the pre-laboratories during semester one, considering previous chemistry experience

Statement	**PC**		**NC**		***t***	***df***	***p***
	Mean	***σ***	**Mean**	***σ***			
Having completed the prelab I was confident I **understood the chemistry theory** relating laboratories	3.58	0.88	3.08	0.87	3.52	147	0.001*
Having completed the pre-lab I was **confident about the practical work** I would complete in the laboratory	3.57	1.01	3.19	0.87	2.43	147	0.016*
I was **well prepared for the experiment** that I would carry out each week	3.58	1.00	3.25	0.82	2.22	146	0.028*

Though only 52% of students were confident about the practical component having completed the pre-laboratory, only 21% felt the practical part was difficult (Table 4.22). Students also found the laboratory reports relatively easy with only 16% indicating they were difficult. Chemistry theory and practical calculations were perceived to be more difficult for the students. 54% and 52% of students respectively found these areas difficult which appears to reflect earlier analysis regarding students' skills where they were more confident in their technical and recording skills than data manipulation. Overall 62% of students felt that the first semester laboratories were challenging but doable with 14% disagreeing with this statement.

Table 4.22: Students' opinion of the challenge posed by the laboratories in the first semester (% agreement)

Statement	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
Overall I found the chemistry labs challenging but doable	148	62	24	14	3.58
I found the theory of the chemistry in the labs difficult	149	54	22	24	3.45
I found practical calculations difficult	149	52	26	22	3.42
I found the practical part of the lab difficult	147	21	29	50	2.69
I found writing a lab report easy	148	58	26	16	3.55

For the most part, male and female students have similar opinions regarding the challenge posed by the laboratories, although female students did find the calculations more difficult ($p = 0.005$). Students who had not studied chemistry previously found the chemistry theory and practical part more difficult than those who studied chemistry at second level (Table 4.23). This was supported by tutor feedback in which 86% of tutors felt that 'students without leaving certificate chemistry struggled more than those who had done chemistry before'.

Table 4.23: Difference in opinion regarding challenge posed by first semester laboratories based on students' previous chemistry experience

Statement	PC		NC		*t*	*df*	*p*
	Mean	σ	Mean	σ			
I found the **theory** of the chemistry in the labs difficult	2.90	1.17	3.95	1.01	5.83	146	0.000*
I found the **practical** part of the lab difficult	2.35	1.02	3.03	0.92	4.22	144	0.000*

Preparation for the 2nd semester laboratories perhaps indicates a rise in student motivation towards the laboratories. 69% of students noted that they tended to prepare more in the second semester. However, 40% of tutors didn't feel students' preparation increased during the semester (Table 4.24).

Table 4.24: Tutors' and students' opinions regarding preparation during the second semester (% agreement)

Tutors	**N**	**Very strongly / strongly agree**	**Somewhat /not sure**	**Very weakly / weakly agree**	**Mean**
Students general **effort** increased as the semester progressed	15	40	47	13	3.47
Students					
I tended to **prepared more** for 2nd semester laboratories	144	69	18	13	3.82

Students point towards increased preparation in the second semester however; this does not appear to correlate with their responses towards their pre-laboratory preparation (Table 4.25). There is no significant increase in the statements, 'I was well prepared for the experiment that I would carry out each week' and 'I was aware of the aim of the experiment before I entered the lab'. Although having completed the pre-laboratories, student highlight a greater confidence in understanding the chemistry theory and in completing practical work in the laboratory when compared to the first semester which reflects their overall increase in confidence in the second semester. There are significant differences observed regarding feedback when both gender and previous chemistry experience is examined. Male students were less confident about the practical work (p = 0.031) and less prepared for the experiments each week (p = 0.034) than female students. NC students expressed comparable views regarding their preparedness for the experiments and confidence regarding the practical work; however, they still found the chemistry theory more difficult (p = 0.028) and were less aware of the aim of each experiment (p = 0.022) compared PC students.

Table 4.25: Change in students opinions towards pre-laboratory preparation from end of semester one to end of semester two

Statement	LE_1		LE_2		t	df	p
	Mean	σ	Mean	σ			
Having completed the pre-lab I was confident I understood the chemistry theory relating to the related laboratories	3.41	0.88	3.66	0.84	2.89	118	0.005*
Having completed the pre-lab I was confident about the practical work I would complete in the laboratory	3.39	0.98	3.60	0.95	2.06	118	0.042*
I was well prepared for the experiment that I would carry out each week	3.47	0.89	3.49	0.90	0.18	117	0.859
I was aware of the aim of the experiment before I entered the lab	4.10	0.82	4.01	0.77	1.16	118	0.251

LE_1 = Laboratory evaluation survey completed at the end of semester 1
LE_2 = Laboratory evaluation survey completed at the end of semester 2

Tutors expressed mixed views regarding students' preparation for pre-laboratories in the second semester. Though 89% indicated that students' pre-laboratory preparation was better than in the first semester, only 40% felt students put a lot of effort into the pre-laboratories and tutors held different views regarding students increasing preparation during the semester (Table 4.26).

Table 4.26: Tutors' opinions of student pre-laboratory preparation at the end of semester two (% agreement)

Statement	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
Students put a lot of effort into the pre-labs	15	40	53	7	3.47
Students put effort into understanding the labs	14	43	36	21	3.29
My students preparation increased as the semester progressed	15	53	14	33	3.27
My students prepared better for 2nd semester labs	9	89	11	0	4.11

Students increased confidence in the second semester cannot be attributed to a decrease in the laboratory challenge posed (Table 4.27). In fact students point towards the second semester being more challenging (p = 0.000). They highlight chemistry theory, practical calculations and writing laboratory reports as being more difficult. There appears to be no increase in difficulties relating to technical skills. As at the end of the first semester, female students find the practical calculations significantly more difficult than male students (p = 0.030), in addition they also found the writing laboratory reports more difficult (p = 0.048) even though they are more confident than male students in terms of recording data in their journals. NC students' expressed similar views as PC students, regarding the overall challenging nature of the laboratories, the practical component and writing laboratory reports, however they still found the chemistry theory significantly more difficult (p =

0.000) and also struggled with the practical calculations more (p = 0.000). Indeed 80% of tutors felt that NC students struggled more in the second semester.

Table 4.27: Change in students' opinions of challenge posed by the laboratories from the end of semester one to the end of semester two

Statement	LE_1		LE_2		*t*	*df*	*p*
	Mean	σ	Mean	σ			
Overall I found the chemistry labs **challenging but doable**	3.64	0.96	4.08	0.80	4.46	111	0.000*
I found the **theory** of the chemistry in the labs difficult	3.33	1.21	3.78	1.12	4.26	112	0.000*
I found **practical calculations** difficult	3.38	1.16	3.79	1.22	4.21	111	0.000*
I found the **practical** part of the lab difficult	2.63	1.01	2.77	1.09	1.36	110	0.177
I found **writing a lab report** easy	3.53	1.06	3.13	1.08	3.40	109	0.001*

The second semester analysis reveals that students appear to have become more independent in the laboratory which reflects the increase in confidence mentioned previously. 93% of tutors pointed towards students becoming more independent in the second semester. 79% of students believed they were more capable of working on their own in the second semester and only 15% of students did not like having to start the second semester experiments on their own (Table 4.28). These findings were emphasised during the group discussions. A tutor observed that, '*Compared to the first semester, the general attitude and work was better. Students were more independent than in the first semester and asked more questions'*. Tutors believed that having students start the experiment on their own whilst they corrected the pre-laboratory contributed to the students becoming more independent. Others noted that the motivation of the students increased temporarily at various points especially if a students had a bad week then they were warned to improve for the following week and some pointed out that motivation increased at the start and then began to reduce in the last few weeks when students felt confident that they had passed the laboratory.

Table 4.28: Tutor and student feedback regarding learning responsibility at the end of semester two (% agreement)

Tutor Feedback	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
My students became more independent carrying out experiments as the semester progressed	15	93	0	7	4.20
My students were more independent carrying out experiments in the 2nd semester	9	89	11	0	4.33
Student Feedback					
I was better able to work on my own in the second semester	144	79	12	9	3.99
I liked having to start the experiment myself without my tutors assistance	140	65	20	15	3.67

(3) Tutor and academic support

In Chapter 3 it was emphasised that small group teaching was an essential aspect of this work to allow for the development of skills, implementation of the assessment system etc. It was important that the tutors interacted well with the students to help create a positive learning environment. Student and tutor evaluations highlight that a good rapport was developed between the two groups in the first semester (Table 4.29). Students indicated that they found the tutors approachable and helpful (mean = 4.23) and that the assessor role of the tutor was not detrimental to students comfort with the tutor (mean = 4.43). Indeed 81%

of students disagreed with the statement, 'I did not like talking to my tutor since s/he was assessing me'. One tutor supported this finding when she stated, '*My students never shied away from asking questions even though I was assessing them'*, this seemed to be the general consensus amongst tutors; however one tutor did comment that, '*students seemed to be under a lot of pressure; some were afraid of 'loosing marks' and were afraid of the tutor marking them – they didn't see it as a chance to gain marks'*.

93% of tutors felt they developed a good rapport with their students during the first semester, though they did express mixed opinions regarding student time demands. Some tutors (43%) found that students demanded their time equally whilst 50%, felt that some students demanded more time from them. This reflects the mixed opinions regarding the statement, 'I spread my time equally amongst all of my students'. This was the case from some (36%) but not for others (50%). 72% of tutors did indicate that they were able to spend their time with students who needed it the most. It is suggested that these mixed opinions perhaps reflect different group compositions in terms of chemical knowledge. Both tutor and student feedback would perhaps indicate that tutors managed to deal with these differing situations.

Analysis of tutor and student responses, in relation to the second semester, highlights similar findings. All tutors felt they build up a good rapport with the students (Table 4.30). Again, they appeared to have different time demands placed on them by students. For example, 33% of tutors note that all of their students demanded their time equally whilst 40% had the opposite experience. For the most part tutors appear to have dealt with this group dynamic, only 13% highlight that they weren't able to spend enough of their time with students who needed it. Indeed tutors highlight that during the laboratories they got to know their students so they were best able to help them. One tutor commented, '*You could see how they were progressing and if you saw someone struggling you knew the best way to attack that'* and another tutor said, *'Having the same students was good since different people have different ways of understanding things and you learned how your different students understood by the way you spoke to them. You learned to ask the same question in different ways so your students understood you. I was a real exercise in communication'*.

Table 4.29: Student and Tutor feedback regarding their interaction with each other during semester one (% agreement)

Student Feedback	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
The lab tutors were approachable and helpful	150	80	11	9	4.23
Even though my tutor was grading me I was comfortable asking him/her questions	149	82	11	7	4.33
I did not like talking to my tutor since s/he was assessing me	149	5	14	81	1.73
Tutor Feedback					
I built up a good relationship with my students	14	93	7	0	4.29
All my students demanded my time equally	14	43	7	50	3.00
I was able to spend time with students who needed my time	14	72	7	21	3.79
I spread my time equally amongst all of my students	14	36	14	50	2.86
Your students did better than the average student	14	25	67	8	3.17

Students are equally positive towards their interaction with tutors during the second semester, 85% felt they were approachable and helpful and the assessment element again didn't appear to impinge on the interaction. In both semesters the findings were consistent when gender and previous chemistry experience was considered.

Table 4.30: Student and Tutor feedback regarding their interaction with each other during semester two (% agreement)

Tutor Feedback	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
I built up a good relationship with my students	15	100	0	0	4.20
All my students demanded my time equally	15	33	27	40	2.80
I was able to spend time with students who needed my time	15	60	27	13	3.67
I spread my time equally amongst all of my students	15	47	27	26	3.40
Your students did better than the average student	15	20	80	0	3.33
Student Feedback					
The lab tutors were approachable and helpful	143	85	10	5	4.33
Even though my tutor was grading me I was comfortable asking him/her questions	143	80	8	12	4.22

A learning environment that encouraged students to engage with laboratory work was deemed to be essential for this laboratory module. Using a variety of experiments, pre-laboratories, a variety of assessment and small group teaching were incorporated to have a positive influence on the student learning experience. In this section both students and tutors opinions on enjoyment, motivation, confidence, preparation, laboratory challenge and interaction with each other have been presented. It was observed that students took time to settle into the laboratory module. Initially they indicate they found the laboratories stressful and were under time pressure to complete the work. They found the theory particularly difficult. Tutors indicated that students didn't apply appropriate efforts towards the pre-laboratories and many students themselves didn't feel confidence towards the laboratories having completed the pre-laboratories. Overall in the first semester only half of the students enjoyed the experience. However, students build up a good rapport with their tutors and the assessment role of the tutors did not appear to impinge on this relationship. Tutors indicate that during the first semester students' confidence and efforts began to increase. This was certainly the case in the second semester. Students appear to have been under less stress within the laboratories. They enjoyed the laboratories more and they have indicated that they prepared more, were more motivated and more confident in the second semester. These findings were supported by tutors, and indeed they indicated that students became more independent in the laboratories and were better able to work without assistance, although some did note that students could have applied more effort towards the pre-laboratories. Students did find the laboratories overall more difficult in the second semester, specifically in relation to laboratory reports, chemical theory and data manipulation. There were some noted differences present at the end of the second semester when gender was considered; for example female students found calculations and writing laboratory reports difficult. Differences were observed in relation to students' previous chemistry experience, where NC students found data manipulation and chemistry theory more difficult, and they were also less confident in the laboratories than PC students. However, NC students enjoyed the laboratories as much as their colleagues and indeed expressed similar responses regarding difficulty of practical element, writing laboratory reports and interaction with the tutors. Overall tutors' comments point towards a good learning environment being created for students where they said, ''*I don't see any negatives; I thought it was a good learning environment. They got to see the practical side of what they were learning which was good. It gives students a better appreciation seeing how things work'* and another commented, '*with the pre-labs and the questioning you are providing the best environment that you possibly can but if they don't want to learn it, well then they will not learn it'*. It does appear with the exception of forming a positive learning relationship with the tutors, students took time to settle into the laboratories; however as they progressed through the year, they adapted to the system and became more confident, more motivated, and ultimately enjoyed the experience more.

4.2.4. Knowledge and Understanding

As highlighted previously, it is suggested that the laboratory can be used to teach chemical knowledge and forge links between theory and practice in addition to teaching practical skills. It was outlined in Chapter 3 how small group teaching, a variety of experiments and assessment formats and pre-laboratories tasks were the actions introduced to allow for the teaching of underlying chemical knowledge. In this section some analysis of student learning based on student and tutor opinion will be presented.

Previously in this chapter it was mentioned how tutor questioning and student-tutor interaction has had a positive influence on learning. It was discussed how questioning and pre-laboratories helped make students more confident in the theory they would cover. Indeed by the end of the first semester, 69% of students agreed that they learned chemistry through the laboratories and 6% of students felt this did not occur (Table 4.31). Further investigation is needed to identify who these students were, but it is suggested they may be students who received high grades in chemistry at second level and perhaps felt the laboratories were not challenging enough or that they could be students who found the laboratories too difficult and decided to not to engage with module. Students have expressed mixed opinions of the problem tasks used in some of the experiments where only 30% have indicated they liked them. However, 71% noted that the tasks made them think about the chemistry in the laboratory and only 6% had the opposite opinion. Similarly, 77% of students pointed towards the questions at the end of each experiment encouraging them to think about what was covered in each experiment. Differences in opinion were observed when gender and chemistry background were considered. Male students felt that the problem tasks made them think more about the experiments compared to female students ($p = 0.048$). Similarly, PC students felt that the problem tasks made them think more too ($p = 0.007$) and indeed, they tended to enjoy the tasks more than NC students ($p = 0.003$).

Table 4.31: Students' opinions towards, their learning in the laboratory, problem tasks and end-of-experiment questions at the end of semester one (% agreement)

Statement	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly/ weakly agree	Mean
I learned chemistry through the lab experiments	149	79	15	6	3.90
I liked the problem tasks (generally task 3) at the end of the lab experiments	149	30	28	42	2.87
The problem tasks (tasks 3) made me think about what I was doing in the laboratory	150	71	23	6	3.79
The questions at the end of each experiment made me think about what was covered in the experiment	147	77	15	8	3.84

In Table 4.32, a breakdown of students' opinions towards each experiment is presented. They have expressed positive views of each experiment. An average of 75% indicated that they like the experiments and an average of 88% believed that they learned from the experiments. Three experiments, Exp 1.5: Acids, bases, indicators and pH, Exp 1.8: Devise an experiment and Exp 1.9: Determination of an ideal gas constant, were highlighted as those most enjoyed by students. Exp 1.2: What is a mole? was by far the experiment least enjoyed. Exp 1.9: Determination of an ideal gas constant and Exp 1.8: Devise an experiment, were the top two experiments which students felt they learned from. Interestingly even though Exp 1.2: What is a mole? was the least liked by students, 90% felt they learned from it. In relation to the statement, 'I have learned from this experiment/activity', Exp 1.10: Identification of the stoichiometry of a metal-ligand complex, was least favoured with 84% agreement to the related statement. Three of the four physical experiments and the introduction to the laboratory were rated as those in which student saw the least purpose to, interestingly this includes, Exp 1.9: Determination of the ideal gas constant, which was one of the experiments liked the most and felt the learned from. Students were mostly positive towards the oral presentation and practical assessment activities, though it is evident that they held a lower opinion of the oral presentation; 34% of the students did not like giving the presentation, 17% felt they didn't learn from it and

84% did not see its purpose. This clearly mirrors students' previous confidence level in giving oral presentations. It is worth noting that even though these were primarily assessment activities, the majority of students felt that they learned from the experience.

Table 4.32: Students' opinions of the experiments carried out in semester one

	I liked the experiment/ activity	**I learned from this experiment/ activity**	**I didn't see the purpose of this experiment/ activity**
Experiment	**Agree %**	**Agree %**	**Agree %**
1.1 Introduction to fundamentals in the lab	77	86	12
1.2 What is a mole?	61	90	6
1.3 Qualitative identification through solubility	73	87	9
1.4 Identification of unknowns	69	91	10
1.5 Acids, bases, indicators and pH	82	91	7
Oral Presentation	66	83	16
Practical Skills Assessment	80	82	10
1.6 What concentration is it?	79	89	9
1.7 Calorimetric determination of enthalpies	70	85	15
1.8 Devise an experiment	80	92	11
1.9 Determination of the ideal gas constant	82	94	14
1.10 Identification of the stoichiometry of a metal-ligand complex	75	84	13

In Table 4.33, it is shown that there were some discrepancies on students' views of the experiments when gender and previous chemical experience were explored. Once again it is noted that female students did not like the oral presentations as much as their male colleagues (p = 0.025). For the other differences, there doesn't appear to be any obvious reason for the differences observed. Further investigation would need to be carried to determine the reasons for these findings.

Table 4.33: Differences of students' opinion regarding semester one experiments when gender is considered

I liked the experiments	Male		Female		*t*	*df*	*p*
	Mean	σ	Mean	σ			
1.2 What is a mole?	0.51	0.50	0.69	0.46	-2.17	124	0.032*
1.5 Acids, bases, indicators and pH	0.74	0.44	0.89	0.32	-2.24	104	0.027*
Oral Presentation	0.76	0.43	0.59	0.50	2.27	134	0.025*
I didn't see the purpose of this experiment / activity							
1.3 Qualitative identification through solubility	0.03	0.18	0.14	0.35	-2.35	124	0.021*
I liked the experiments							
1.4 Identification of unknowns	0.80	0.40	0.58	0.50	2.91	139	0.004*

Students expressed similar positive opinions at the end of the second semester towards their learning in the laboratories (Table 4.34). 82% felt they learned chemistry through the laboratories. 90% indicated that the problem task 'Selggog Abbey' helped them link the chemistry studied to real life applications. Significantly more students (83%) felt that the questions at the end of the experiments made them think about the chemistry covered (p = 0.000). This increase may have been related to students being able to complete the questions outside of laboratory time in the second semester. Indeed 99% of students indicated that they liked having this option.

Table 4.34: Students' opinions of their learning in the laboratory during semester two (% agreement)

Statement	N	Very strongly/ strongly agree	Somewhat /not sure	Very weakly /weakly agree	Mean
I learned chemistry through the lab experiments	137	82	15	3	4.06
The water problem 'Selgogg Abbey' made me link the chemistry I have done to 'real-life' applications	143	90	8	2	4.44
The questions at the end of each experiment made me think about what was covered in the experiment	141	83	11	6	4.19

Students impressions of the individual experiments carried out in semester two are presented in Table 4.35. In relation to these students responded positively towards the statement 'I liked the experiment/activity'. Only three experiments received lower than 80% agreement. Two of these were analytical experiments and one an organic experiment; Exp 1.3: Determination of an equilibrium constant (60%), Exp 1.4: Spectrophotometric determination of an equilibrium constant (61%) and Exp: 1.8 Dehydration of alcohol and isolation of its products (71%). The top two experiments which students liked were the analytical experiments, Exp 1.1: Determination of water hardness using EDTA titration (89%) and Exp 1.2: Analysis of Rubex by back titration (87%). A 90% average response was noted towards the statement 'I learned from this experiment/activity'. Indeed a score above 90% was noted for 7 of the 10 experiments as shown in Table 4.35. The experiments in which students felt they learned from mostly reflected the experiments which they indicated they liked. Consistent findings were observed in students' responses to the statement, 'I didn't see the purpose of this experiment/activity'. An average of 89% of students disagreed with the statement. In relation to the oral presentation and the practical assessment, as with the first semester evaluation, students have noted that they favoured the practical assessment and a relatively high percentage (40%) did not like the oral presentation. That said, 83% of students felt they learned from the oral presentation and 86% saw the purpose of the activity.

Table 4.35: Students' opinions of second semester experiments

	I liked the experiment/ activity	I learned from this experimen t/activity	I didn't see the purpose of this experiment/ activity
Experiment List	**Agree (%)**	**Agree (%)**	**Agree(%)**
2.1 Det. of water hardness using EDTA titration	89	91	6
2.2 Analysis of Rubex by back titration	87	96	10
2.3 Det. of dissociation constant of a weak acid	60	84	14
2.4 Spec determination of an equilibrium constant	61	84	19
2.5 Solid-liquid extraction of Trimyristin from nutmeg	82	92	10
2.6 'Selgogg Abbey'	84	91	7
Oral Presentation (2)	60	83	14
Practical Skills Assessment (2)	80	85	7
2.8 Dehydration of alcohol and isolation of it's products	71	88	17
2.10 Synthesis of Aspirin	84	91	8
2.11 Hydrolysis of Trimyristin	81	90	8
2.12 Qualitative determination of functional groups	80	91	9

There was no difference in students overall views of learning in the laboratory when gender and previous chemistry experience were examined. However, some differences were observed in relation to opinions on each experiment/activity (Table 4.36). There was only one difference noted between PC and NC students which related to Exp 1.1: Determination of water hardness using EDTA. In this case, NC students felt they learned more from the experiment. More differences were noted when gender was taken into account. Again it is observed that female students didn't like the oral presentations, though they were more favourable towards Exp 1.1, which they indicated they liked and learned from more than their male colleagues.

Table 4.36: Differences in students' opinions regarding semester two experiments based on gender

I liked the experiment/activity	Gender	Mean	σ	*t*	*df*	*p*
1.1 Det. of water hardness using EDTA titration	Male	0.79	0.41	3.48	124	0.001*
	Female	0.97	0.16			
Oral Presentation	Male	0.76	0.43	3.13	125	0.002*
	Female	0.49	0.50			
I learned from this experiment/activity						
1.1 Det. of water hardness using EDTA titration	Male	0.84	0.37	2.39	62	0.020*
	Female	0.97	0.16			
1.11 Hydrolysis of Trimyristin	Male	0.83	0.38	1.95	69	0.055
	Female	0.95	0.22			
I didn't see the point of this experiment/activity						
1.4 Spec determination of an equilibrium constant	Male	0.27	0.45	2.06	81	0.043*
	Female	0.11	0.32			
1.12 Qualitative determination of functional groups	Male	0.16	0.37	2.37	31	0.023*
	Female	0.00	0.00			

Overall students in both semesters have been positive towards their learning of chemistry through the laboratories. For the most part, it has been observed that students liked and particularly learned from the individual experiments. It was also seen that they believed the assessment activities, oral presentations and practical assessment were beneficial to their learning of chemistry. There was little difference expressed by students with differing chemistry experiences when asked about their overall learning in the laboratory. The largest differences were noted when gender was investigated. There are little trends obvious to explain these differences except in relation to oral presentations which female students appear to dislike more than their male colleagues.

4.3 Implementation of Laboratories – Tutor Perspective:

Thus far, student and tutor responses regarding students' actual experiences of the laboratories have been presented. However, some aspects of the laboratory implementation such as tutor's confidence, preparedness and experiences of implementing the assessment system have not been discussed. In this section, an overview of the laboratory implementation from the tutors' perspective will be discussed.

4.3.1 Tutor Training and Support

The training workshops provided to the tutors has previously been outlined in Chapter 3. In Table 4.37, tutors feedback regarding the first training workshop is presented. They gave mostly positive feedback in which they indicated that the training was relevant towards their tutor experience (mean = 4.17) and that having completed the training they were more aware of the expectations on them (mean = 4.00) and the importance of their role (mean = 4.08). They also noted that the workshop 'increased (their) interest in and enthusiasm for the task of tutoring' (mean = 4.00). Overall, the training workshop appeared to have been beneficial to the tutors. During the group discussions, one tutor commented, '*It gave you an idea of what was expected of you, when you were asked what your tutors were like it reminded you of what tutors did and made you think about how you would do it'*. Another tutor noted that the workshop was a good way for tutors to get to know each other and talk about tutoring experience and it was a '*good opportunity to voice your worries about tutoring'*. However a recurring negative view mentioned was over emphasis on people/communication skills which tutors felt became too repetitive. One tutor noted, '*Training workshops were about people skills; assuming your people skills were ok it wasn't really of any benefit'*.

Tutors were asked to express their perceived level of preparedness for 1st semester tutoring (Table 4.38). They felt they knew what was expected of them and they were prepared for working with the students; all of the tutors agreed with the statement, 'I felt prepared to interact with the students'. They highlight a general confidence in their level of preparedness in relation to both the chemistry content and practical activities and indicate that they felt supported throughout the semester. They were positive in relation to the statements 'If I was unsure about any aspect I was able to ask someone for advice/help' (mean = 4.46) and 'The handouts of the experiments were useful' (mean = 4.54).

Table 4.37: Tutors' opinions of the training workshop provided (% agreement

Statement	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
The training workshop increased my awareness of what was to be expected in labs/tutorials	12	75	25	0	4.00
The training workshop increased my interest in and enthusiasm for the task of tutoring	12	67	33	0	4.00
The training workshop increased my awareness of the importance of my role as a tutor	12	83	17	0	4.08
The training workshop increased my awareness of the importance of empathising with students in my classes	12	83	17	0	4.08
Overall, I think the training workshop helped to make me a more effective tutor	12	83	17	0	4.08
Overall, I think the training workshop was relevant to the job I am doing as a tutor	12	83	17	0	4.17
I think I learned some valuable skills in the training workshop	12	58	42	0	3.83

However, a couple of tutors felt the handouts should have been given as a manual with 'step by step instruction on how to do the experiments, extra background theory, guideline questions and training on each experiment'. Also some were less positive towards the benefit of 'being able to do the experiments on the Wednesday before the laboratory session'. Two tutors note they did not find this of any benefit and in fact these tutors did not avail of the opportunity. Indeed very few tutors made use of this option. Though there was a general consensus that the weekly meetings were beneficial, tutors suggested that they took up too much of their research time and would prefer to have one general meeting in which all of the experiments were discussed. This pressure on their research time may also have been an explanation for tutors not taking up the opportunity to do the experiments during the additional slot provided

Table 4.38: Tutors' perceived level of preparedness for first semester tutoring (% agreement)

Statement	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
I felt prepared in relation to the chemistry being covered in the laboratory sessions	13	84	8	8	4.00
I felt I was prepared in relation to the practical activity that was being coved in the laboratory	12	92	8	0	4.08
I knew what was expected of me within the labs	13	77	23	0	4.08
I felt I was prepared to interacting with students	13	100	0	0	4.23
If I was unsure about any aspect I was able to ask someone for advice/help	13	92	8	0	4.46
It was helpful to be able to do the experiments on the Wednesday before the laboratory session	12	75	8	17	3.75
The handouts of the experiments were useful	13	92	8	0	4.54
I prepared for each lab session before entering the lab	14	93	7	0	4.36

Tutor feedback regarding their preparedness for second semester was comparable with that observed after semester 1 (Table 4.39). Their response to the statement 'I knew what was expected of me within the labs' was scored similar at the end of each semester (4.08 and 4.07 respectively).There was a very slight decrease observed for the statement, 'If I was unsure about any aspect I was able to ask someone for advice/help' (4.46 and 4.40 respectively). Agreement to the statement, 'I felt I was prepared to interacting with students' decreased from a mean score of 4.23 to 3.93, although none of the tutors disagreed with the statement. Indeed, during the discussions session, one tutor noted,

'*I don't think we could have been better prepared. I did second year labs this year too and basically I went in with a lab book and that was it. I had to figure out for myself what problems they would have and how to correct their reports and compare to this we had sheets and training at the start. I thought we were really well prepared. I think if we had any more preparation it would be verging on spoon feeding.'*

Other tutors agreed with this sentiment and reiterated that the experimental sheets were very beneficial, though one tutor felt that the calculations in the experimental sheets were not detailed enough and they should have been done out stepwise. Other tutors mentioned that it was good that they were given the opportunity to do the experiments before hand even though they didn't take up the opportunity. They indicated that their research commitments didn't give them enough time to do this. Overall, tutor feedback is positive regarding both the training, and continued support they received during the module. In the next section, tutors experiences of implementing the assessment system will be discussed.

Table 4.39: Tutor perceived preparedness for second semester laboratories (% agreement)

Statement	N	Very strongly / strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
I felt prepared in relation to the chemistry being covered in the laboratory sessions	15	93	0	7	4.20
I felt I was prepared in relation to the practical activity that was being coved in the laboratory	15	80	13	7	4.13
I knew what was expected of me within the labs	15	83	20	7	4.07
I felt I was prepared to interacting with students	15	60	40	0	3.93
If I was unsure about any aspect I was able to ask someone for advice/help	15	87	13	0	4.40
The handouts of the experiments were useful	15	87	13	0	4.60
I prepared for each lab session before entering the lab	15	87	13	0	4.47

4.3.2 Assessment Implementation

In relation to the practical details of the assessment, tutors point towards a general confidence in knowing how to assess the pre-laboratories, students understanding and the student laboratory journal (Table 4.40). Tutors were least confident (69%) regarding their understanding of how assess the laboratory journal and they were most confident regarding the assessment of the pre-laboratories (92%) and assessment of students understanding within the laboratory (85%). Tutor responses do highlight some concerns regarding the assessment implementation in the first semester. Though they understood how the assessment was to be implemented, they identified difficulties such as correcting the journals and providing feedback for the pre-laboratories and the journal. Only 7% of tutors felt that it was possible to provide feedback on the journals within the laboratory time. During the discussion with tutors, they pointed out that the pre-laboratory correcting (both assignment and questioning) took up a lot of time and they felt they didn't have enough time to complete the other assessment elements. Some also indicated that they got caught up helping students finish the experiments and as a result had little time to correct the journals, and since, in some cases, students were not finished until the very end of the session, thus they could not correct the entire journal as the laboratory session was finished. Some tutors (28%) also appear to have found it difficult to ask challenging questions in the laboratory and 65% felt they would prefer to correct the journals outside of the laboratory time. As a result tutors were given this option for the second semester as mentioned in chapter 3.

Table 4.40: Tutor feedback regarding the implementation of the laboratory assessment during the first semester (% agreement)

Statement	N	Very strongly/ strongly agree	Somewhat /not sure	Very weakly / weakly agree	Mean
I understood how I was going to assess the students pre-labs	13	92	8	0	4.31
I understood how I was going to assess the students understanding of the experiment	13	85	14	0	4.00
I understood how I was going to assess the students journal	13	69	23	8	3.77
It was possible to correct pre-labs during the lab session	14	79	14	7	4.00
It was possible to give student feedback on the pre-labs	14	57	29	14	3.64
It was possible to correct the journals within the lab	14	21	14	65	2.29
It was possible to give feedback on the journals within the lab	14	7	36	57	2.21
I found it easy to ask students challenging questions	14	36	36	28	3.14
I'd prefer to correct the lab journal outside of the lab	14	65	14	21	3.86

In the second semester, tutors responses' indicate that they better understood how to implement the assessment elements (Table 4.41). They also note that they were better able to correct and provide feedback in relation to the pre-laboratories. They found it easier to implement the questioning during the laboratory. One tutor said, *'I enjoyed the questioning and students got used to it and answering questions while they were working. I don't think there was too much questioning'*, another tutor agreed and commented, *'Questioning got easier as the weeks went on and I knew which questions I could ask and when for example I'd ask more difficult questions when students were waiting on a reflux to complete'*. Though the tutors found it easier to incorporate questioning during the laboratories, the majority still indicate they couldn't correct the laboratory journal during the laboratories and as a result provide feedback to the students on the journal in that laboratory.

Table 4.41: Tutor feedback regarding the implementation of the laboratory assessment during the second semester (% agreement)

Statement	**N**	**Very strongly / strongly agree**	**Somewhat /not sure**	**Very weakly / Weakly agree**	**Mean**
I understood how I was going to assess the students pre-labs	15	100	0	0	4.53
I understood how I was going to assess the students understanding of the experiment	15	93	7	0	4.27
I understood how I was going to assess the students journal	15	87	7	6	4.07
It was possible to correct pre-labs during the lab session	15	80	13	7	4.13
It was possible to give student feedback on the pre-labs	15	93	7	0	4.27
It was possible to correct the journals within the lab	15	7	13	80	1.93
It was possible to give feedback on the journals within the lab	15	20	27	53	2.27
I found it easy to ask students challenging questions	15	40	40	20	3.33

However, to address this, some tutors took the option to correct the journal outside of the laboratory and provide feedback the following week, a tutor commented: '*From a tutor point of view, a positive was that each tutor had the option to correct the journal in the lab or take it home, depending on how they worked with their students'*. It is encouraging that the changes made to the implementation improved the assessment of the pre-laboratories and questioning. However, the assessment of the laboratory journal and the provision of timely feedback in relation to the journal should be addressed in the future.

4.3.3 Tutors Impression of Laboratory Experiments

Tutors feedback in relation the individual experiments are provided in Table 4.42. Tutors indicated a mostly favourable response towards the four statements: 'Experiments were of suitable level for the students', 'aims were clear', 'manual was clear', and 'questions in manual were clear'. In the case of all but one of the first semester experiments, the majority of students agreed with the statements. The introduction tasks and Exp 1.8 received the highest level of agreement to the statements from the tutors while Exp 1.7 stands out as an experiment that needs future amendments. Though the majority of tutors felt the aims of the experiment and the questions at the end of the experiment were clear, they felt that the experiment was too difficult for the students and that the manual was unclear.

During the discussion session, Exp 1.8 was singled out by some tutors as the best experiment in the semester. They noted that by not having a procedure in the manual, students tended to prepare more for this experiment and performed well on it as a result. Exp 1.2 and Exp 1.3 were identified as those with most issues and tutors felt that there was too much to complete in both experiments. In relation to Exp 1.2 a tutor proposed more practicals like making up solutions would be more beneficial to the students. Following on from this point, another tutor suggested that the best parts of the experiment were the later tasks and that unfortunately many students didn't get to complete; '*Tasks two and three were the good practical parts of the experiment but they (the students) didn't get to do them because they spent so long on the ring question'*. In relation to Exp 1.3, some of the tutors noted that there was too much to do in the experiment, and that students were unable to complete it as a result. The tutor noted that the students struggled with writing equations and that perhaps these could be done outside the laboratory. The tutors also noted that the students didn't appear to realise how beneficial it would have been if they had spent more time on their pre-laboratory for this experiment as they would have been able to do more of it if they were better prepared. Tutors comments appear to support students' views that, especially in the early experiments, there was perhaps too much material to be covered within the allocated time.

Table 4.42: Tutors' impression of semester one experiments (% agreement)

	Suitable level for the students	Aims were clear	Manual was clear	Questions in manual were clear
Experiments List	**Agree**	**Agree**	**Agree**	**Agree**
1.1 Introduction to fundamentals in the lab	100	100	100	100
1.2 What is a mole?	85	85	77	85
1.3 Qualitative identification through solubility	85	85	58	91
1.4 Identification of unknowns	100	92	85	92
1.5 Acids, bases, indicators and pH	92	92	92	100
1.6 What concentration is it?	86	100	86	93
1.7 Calorimetric determination of enthalpies	36	82	36	70
1.8 Devise an experiment	100	100	75	100
1.9 Determination of the ideal gas constant	91	92	64	91
1.10 Identification of the stoichiometry of a metal-ligand complex	75	83	83	83

As with the first semester experiments, tutors indicated positive impressions of the experiments in terms of suitability level and clarity of the aims, manual and end of experiment questions for the second semester. In fact, they were slightly more favourable of the second semester experiments (Table 4.43). Exp 2.3 and Exp 2.12, received the least level of tutor agreement in relation to the four statements though this was still mostly positive. Some tutors felt that the manual was not clear for these experiments. Some tutors also indicated that Exp 2.12 was not at an appropriate level for the students and that both the aims and questions in the manual were unclear.

Table 4.43: Tutors' impression of semester two experiments (% agreement)

	Suitable level for the students	Aims were clear	Manual was clear	Questions in manual were clear
Experiment List	**Agree**	**Agree**	**Agree**	**Agree**
2.1 Det. of water hardness using EDTA titration	100	100	93	100
2.2 Analysis of Rubex by back titration	93	100	100	100
2.3 Det. of dissociation constant of a weak acid	80	87	67	87
2.4 Spec determination of an equilibrium constant	87	100	80	100
2.5 Solid-liquid extraction of trimyristin from nutmeg	93	100	93	100
2.6 'Selggog Abbey'	93	93	87	100
Oral Presentation (2)	100	100	100	100
Practical Skills Assessment (2)	100	100	93	100
2.8 Dehydration of alcohol and isolation of it's products	93	100	100	93
2.10 Synthesis of Aspirin	100	100	100	100
2.11 Hydrolysis of trimyristin	100	100	100	100
2.12 Qualitative determination of functional groups	79	79	71	79

In the group discussion, Experiments 2.1, 2.2 and 2.6, were identified as the best experiments by the majority of tutors. They felt that students really grasped what was being done in the first two experiments. They felt that the 'Selggog Abbey' experiment was beneficial, as students had to work in groups, which the tutors felt was a good learning experience for the students, as in some groups certain students were a little lazy and the students had to address this issue. One tutor noted, '*Some of the experiments were a little* *abstract but the ones that had a real practical application such as the water problem really worked. It was a really great part of the learning experience'*. Tutors felt that in this experiment, students had the opportunity to see the benefit of some of the previous experiments, and to apply what they had learned to a practical situation. However, they did suggest that there should have been a greater variety in the requirements for the oral presentations. They felt that the presentations in the first semester worked better, and thought that, if each group had to present their findings on one specific river in more detail, the presentations would have been more interesting.

Exp 2.3 was highlighted as one in which students struggled with the calculations. Contrasting opinions were expressed in relation to Exp 2.12. One tutor thought it was hard to follow and wasn't surprised that students lost interest in it. In comparison, another tutor said that the experiment was good, but that students were not interested in it since it was the last day of the year. This was supported by another tutor who said, '*It wasn't difficult, it just required that they think; which is something they will not do in the last week'*. Though, another tutor had positive experiences with the experiment. She stated, *'I had two groups and they loved that experiment, the found it simple enough and interesting'*. Obviously different group dynamics and perhaps the different time slots within the last week had an impact.

4.4 Student academic achievement in the laboratory assessment elements

In this chapter, it has already been shown how the assessment structures used have influenced student learning, preparedness and confidence. In light of tutor and student opinion previously discussed, this section will examine student academic achievement in the various assessment elements, in order to determine the extent of student learning in the laboratory module. Additionally, an analysis of data obtained to determine if the laboratory examination assessments correlate with the marks awarded during the laboratories will be presented.

4.4.1 Student overall academic achievement in laboratory assessments

In Table 4.44, the overall student average marks for the various assessment elements are given. For comparison purposes the data has been standardised out of 100%, though different weightings were used in the actual assessment as outlined in Chapter 3. In both semesters a reasonably small spread of results were observed. Laboratory skills and oral presentations are the two elements with highest scores in both semesters whilst formal laboratory reports received the lowest average result of the two semesters. The high grade awarded for laboratory skills reflects students confidence in technical skills and laboratory safety previously mentioned. However, the high score in oral presentations and relatively low score for formal laboratory reports appears contradictory to student's indicated confidence in these areas. Previously, students indicated they found writing laboratory reports relatively easy in the first semester and expressed a lack in confidence in making oral presentations.

Overall students generally tended to perform better in the second semester compared to the first which does reflect both their and tutor responses that point towards students being more confident, prepared and motivated in the second semester. In Table 4.44, *t*-test analysis comparing students' performance in the assessment elements in each semester is given. It should be noted that only students who completed both tests were included in the analysis. These results show a significant increase in student achievement between first and second semester (p = 0.000) which reflects students improved confidence in the second semester. Two of the eight assessment elements, pre-laboratory task and lab questioning, show no change between the semesters. However, an increase in performance is noted for pre-lab questioning (p = 0.000), laboratory skills (p = 0.019) and the laboratory examination (p = 0.044) from semester one to semester two. Similarly, a decrease is noted in three of the assessment elements; laboratory journal (p = 0.000), oral presentation (p = 0.002) and laboratory reports (p = 0.000).

Table 4.44: Overall comparison of students' achievement in the laboratory assessment elements

Assessment Element	Semester 1		Semester 2		*t*	*df*	*p*
	Mean	σ	Mean	σ			
Overall Laboratory Mark	65	8.61	69	12.24	-5.84	159	0.000*
Pre-Laboratory Total	72	10.25	73	10.98	-1.67	159	0.096
Pre-Laboratory Task	70	14.00	72	14.42	-1.30	159	0.196
Pre-Laboratory Questioning	69	12.31	74	10.95	-4.21	159	0.000*
Laboratory Questioning	71	9.00	73	10.06	-1.91	159	0.058
Laboratory Journal	70	11.74	66	11.85	3.97	159	0.000*
Laboratory Skills	77	9.46	79	8.63	-2.36	159	0.019*
Laboratory Exam Total	66	13.04	68	13.11	-2.03	153	0.044*
Laboratory Reports	65	13.89	52	19.25	3.08	150	0.002*
Presentations	80	10.38	76	12.17	7.02	138	0.000*

In Table 4.45 and 4.46, Students' performance based on previous chemistry experience, is shown for each semester. In the first semester, PC students performed significantly better than NC students. PC students achieved higher grades than NC students in the various assessment elements with the exception of laboratory skills and laboratory reports. In the second semester, NC students, faired slightly better in comparison with PC students than in the first semester. In addition to laboratory skills, and laboratory reports, NC students received similar grades for laboratory journals and oral presentations. However, PC students still achieved greater grades overall and specifically in their pre-laboratory marks, laboratory questioning and laboratory examination. It appears that at the end of the first year there is still a significant difference evident based on students' previous chemistry experience.

Table 4.45: Students' achievement in the laboratory assessment elements in semester one, based on previous chemistry experience

Semester 1 Assessment	PC		NC		*t*	*p*
	N	Mean	N	Mean		
Lab Total	73	68	80	62	3.95	0.000*
Pre-Lab total	73	75	80	69	4.20	0.000*
Pre-Lab Task	73	74	80	68	2.55	0.012*
Pre-Lab Questioning	73	71	80	66	2.48	0.014*
Lab Questioning	73	75	80	68	4.59	0.000*
Lab Journal	73	73	80	68	3.07	0.003*
Lab Skills	73	78	80	76	1.60	0.111
Exam	74	71	73	62	4.80	0.000*
Presentation	71	84	77	77	3.86	0.000*
Report	68	66	73	64	1.15	0.253

Table 4.46: Students' achievement in the laboratory assessment elements in semester one, based on previous chemistry experience

Semester 2 Assessment	PC		NC		*t*	*p*
	N	Mean	N	Mean		
Lab Total	73	73	80	66	3.95	0.000*
Pre-Lab total	73	76	80	71	3.13	0.002*
Pre-Lab Task	73	76	80	69	3.03	0.003*
Pre-Lab Questioning	73	76	80	72	2.68	0.008*
Lab Questioning	73	75	80	72	2.18	0.031*
Lab Journal	73	68	80	65	1.41	0.160
Lab Skills	73	78	80	79	-0.78	0.434
Exam	74	73	73	64	4.66	0.000*
Presentation	72	77	76	74	1.49	0.138
Report	69	55	73	49	1.78	0.077

A similar comparison in laboratory performance between the two semesters based on gender differences is presented in Table 4.47 and 4.48. In both semesters, the female students have performed significantly better than their male colleagues in the 'laboratory journal' and 'report writing' assessment elements. This reflects previous findings indicating female students' greater confidence in keeping a laboratory journal but is contradictory regarding their confidence in writing laboratory reports. Male and female students achieved similar grades in pre-laboratory tasks, pre-laboratory questioning, laboratory skills and laboratory understanding questions and also in the laboratory examinations.

Table 4.47: Students' achievement in the laboratory assessment elements in semester one, based on gender

Semester 1 Assessment	Male		Female		*t*	*p*
	N	Mean	N	Mean		
Lab Total	66	65	94	64	0.21	0.831
Pre-Lab total	66	71	94	72	-0.54	0.588
Pre-Lab Task	66	69	94	71	-1.11	0.295
Pre-Lab Questioning	66	69	94	69	0.11	0.916
Lab Questioning	66	71	94	72	-0.19	0.852
Lab Journal	66	68	94	72	-2.02	0.045*
Lab Skills	66	75	94	78	-1.65	0.101
Exam	65	68	89	65	1.35	0.191
Presentation	65	79	91	80	-0.41	0.680
Report	64	61	84	67	-2.29	0.024*

Table 4.48: Students' achievement in the laboratory assessment elements in semester two, based on gender

Semester 2 Assessment	Male		Female		*t*	*p*
	N	Mean	N	Mean		
Lab Total	67	67	94	71	-1.74	0.084
Pre-Lab total	67	72	94	74	-0.72	0.475
Pre-Lab Task	67	71	94	73	-0.78	0.437
Pre-Lab Questioning	67	73	94	74	-0.56	0.574
Lab Questioning	67	73	94	73	0.16	0.875
Lab Journal	67	62	94	68	-3.13	0.002*
Lab Skills	67	77	94	80	-1.70	0.091
Exam	65	69	89	68	0.42	0.678
Presentation	65	76	91	75	0.61	0.546
Report	59	47	90	56	-2.98	0.003*

In summary, the analysis of the laboratory assessment elements has shown that the marks students obtained for the overall laboratory mark are comparable to that of the laboratory examinations. In both semesters students achieved the highest marks for laboratory skills and oral presentations and they were awarded the lowest marks for formal laboratory reports. The remaining assessment elements received comparable marks. In semester one there was a spread of 15% between all of the average marks awarded and 27% in the second semester. Overall, students performed significantly better in the second semester than in the first, where they specifically achieved better results in the pre-laboratory questioning, laboratory skills and examination elements, though, it was observed that significantly lower marks were awarded for journals, written reports and presentations in the second semester. The lower marks for laboratory reports and oral presentations maybe somewhat explained by the higher expectation from the marking systems used for these elements in the second semester. Little differences were observed when the gender issue was explored, though female students did perform significantly better in both semesters in the journal and laboratory reports which reflect their confidence in these areas over their male colleagues. Previous chemistry experience was a significant predictor of student success. In the first semester, laboratory skills and written reports were the only elements in which the two groups scored comparable grades. In the second semester, laboratory skills, written reports, oral presentations and journals were scored similarly by the two groups, although PC students significantly out performed those NC students in the overall marks for each semester and in the total laboratory mark.

4.4.2: Student performance in laboratory examinations

In Chapter 3, Section 3.4.2, an outline of the laboratory examinations used in this work was presented. In this section the laboratory examination questions used, are categorised based on the key elements listed previously in Table 3.4. These questions assessed students' skills and chemical knowledge; the categorisation of these is given in Table 4.9. Students' achievement in the various categories will be presented and a comparison based on previous chemistry experience and gender will be given.

Table 4.49: Key elements assessed through the laboratory examination

Skills	Knowledge and Understanding
Technical skills	Moles, calculations and titrations (A)
Observation skills	Acids and bases (B)
Data Manipulation	Balancing and writing equations (C)
Data Interpretation	Practical knowledge (D)
-	Units of concentration (E)

For data presentation purposes, the knowledge and understanding topics have been separated into five categories (A-E) as in Table 4.49. A breakdown of the individual questions used in laboratory examinations based on this categorisation is given in Table 4.50. There are some questions which overlap between categories and one question did not fit into any of the category. This question (disposal of chemicals) relates to laboratory safety however, it was felt that this question alone could not be justified to give a measure of students' awareness of laboratory safety. Indeed it is felt that laboratory safety is one component of the work that though assessed through skills marks and this examination question it is not specifically assessed by an identifiable mark. In Table 4.50, the bottom row presents the frequency of the questions for the individual categories e.g. 'Technical Skills' are assessed most; eleven questions were asked between the two papers.

For the purpose of the analysis students marks in the questions related to each specific category were summed and standardised out of 100 per cent. Thus for students 'Data Interpretation' score in the second semester, students' grades in questions, 3, 5 & 7 in part A of the second semester examination paper were totalled with students grades in question 4 in part B of the same paper. The total score was divided by the total possible mark for these questions and converted to a percentage.

In Section 4.4.1, students overall performance in the laboratory examinations was given. It was observed that students received an average of 66% in semester one and 68% in semester two. In Table 4.51, students' marks based on the categorisation discussed are presented. Students were awarded their best marks for technical (74% and 81%) and observation skills (72% and 84%). This trend is consistent for both semesters and reflects students' confidence in their skills. Equally, data manipulation is noted as the item in which students received lowest grades, 47% and 61%. This too is reflected in students' responses regarding skills confidence. The greatest spread in marks is also noted for data manipulation which had a standard deviation spread approximately double that of technical skills.

With respect to the 'underlying knowledge' categories a less consistent trend is noted between the two semesters. In the first semester students performed best on categories A and B scoring 64% and 63% respectively. This was followed by category C with a score of 52%. The lowest marks were awarded for category E (36%) and category D (27%). The two lowest grades also had the highest spread of marks. In the second semester, students performed best in category B by 25% with an average mark of 89%. Categories E and A obtained average scores of 64% and 60% respectively. Categories D and C scored the lowest average mark where average scores of 49% and 38% were awarded. Students appear to have improved their understanding regarding acids and bases, general practical knowledge and units of concentration. However, they appear to have struggled more with balancing and writing reaction equations in the second semester.

In Table 4.51, *t*-test results are also given which compare students performance between semester one and semester where only students' who completed both examinations were considered in the analysis. Students' performed significantly better in three of the skill items. Data interpretation was the only item that did not change between the two semesters. Significant increases in performance in the second semester were noted in Categories B, D and E. Students knowledge of moles, calculation and titrations was consistent between the two semesters.

Table 4.51: Comparison of students' laboratory examination performance between semester one and semester two

Examination Performance	**Semester 1**		**Semester 2**		***t***	***df***	***p***
	Mean	***σ***	**Mean**	***σ***			
Exam Total	66	13.04	68	13.11	2.03	153	0.044*
Technical Skill	74	15.46	81	11.52	4.57	153	0.000*
Observation Skill	72	20.05	84	20.42	5.48	153	0.000*
Data Manipulation	47	30.41	61	30.31	4.64	153	0.000*
Data Interpretation	67	23.32	69	20.81	0.43	153	0.672
Underlying knowledge							
Cat A (moles,calcs,titr)	63	22.18	60	31.91	1.80	153	0.074
Cat B (acids & bases)	64	21.79	89	20.72	11.57	153	0.000*
Cat C (bal/writ eqns)	52	22.28	38	33.40	6.89	153	0.000*
Cat D (prac knowl)	27	32.73	49	24.87	6.59	153	0.000*
Cat E (units of conc)	36	36.88	64	31.83	7.93	153	0.000*

Table 4.50 Categorisation of laboratory examination questions

Laboratory Examination Paper Breakdown	Technical Skill	Observational Skill	Data Manipulation	Data Interpretation	Cat A	Cat B	Cat C	Cat D	Cat E	Other
Semester 1 (Part 1)										
Q1: Units of Concentration									✓	
Q2: Titration calculations			✓		✓					
Q3: mole concept in titrations								✓		
Q4: Balances	✓									
Q5: Glassware	✓									
Q6: Anions & Cations/ balancing eqn / sol. rules							✓			
Q7: Chemical disposal / concentrations										✓
Q8: Acids/Bases, pH and Indicators				✓		✓	✓			
Q9: Moles and Volume			✓		✓					
Semester 1 (Part 2)										
Q1: Acids, bases, pH	✓	✓				✓				
Q2: Concentration & Colour		✓			✓					
Q3: Concentration, colour and volume		✓			✓					
Q4: Inorganic reactions	✓	✓								
Q5: Burette usage ands recording	✓									
Q6: Making solution in Vol. Flask	✓									
Semester 2 (Part 1)										
Q1: Units, concentrations and mole conversions			✓		✓					
Q2: Units of concentration									✓	
Q3: Graph reading (Abs vs Concentration)			✓	✓						
Q4: UV-Vis Blanks								✓		
Q5: Titration Calculation			✓	✓	✓		✓			
Q6: Molarity to ppm conversion			✓		✓					
Q7: EDTA Titration (practical problems)	✓			✓				✓		
Q9: Reflux								✓		
Q10: Extractions (lavender oil)	✓		✓					✓		
Q11: Limiting reagents and calculations							✓			
Semester 2 (Part 2)										
Q1: Set up a reflux	✓									
Q2: Burette (reading only)		✓								
Q3: Set up a vacuum filtration	✓									
Q4: Equilibrium reactions	✓	✓		✓		✓				
Frequency of Questions asked	11	6	7	5	7	3	4	5	2	1

In the overall analysis of the laboratory module it was observed that PC students outperformed NC students. It was also noted that very little difference was apparent when student gender was considered. The analysis of the laboratory examination based on the categorisation outlined has shown similar findings (see Tables 4.52 - 4.55). In semester one, PC students performed better than NC students in all but two of the categories. The exceptions were 'Observation skill' and 'Category E – knowledge of units of concentration'; in these cases there were no significant differences noted between the two groups. Similar findings were found in the second semester. Once again there was no difference noted in terms of 'Observation Skills' and 'Category E', in addition to these two comparable grades were achieved in relation to 'Category B – knowledge of acids and bases' in the second semester (Table 4.52-4.53). However, this implies that during the second semester there were significant differences present regarding technical skills, data manipulation, data interpretation, doing calculations, balancing equations and practical knowledge. This is of particular concern in relation to balancing equations and practical knowledge as students without chemistry scored particularly poorly in these elements and highlights an area that needs to be addressed in future work. When gender differences were examined no significant differences were observed in students' performance in the first semester. In the second semester both male and female received analogous grades with the exception of 'Category D – practical knowledge' in which the male students obtained higher grades than their female colleagues (Table 4.54 and Table 4.55).

Table 4.52: Students performance in the laboratory examination elements in semester one based on previous chemistry experience

Semester 1 Examination Performance	PC		NC		*t*	*p*
	N	Mean	N	Mean		
Skills						
Technical Skill	79	78	83	72	2.87	0.005*
Observation Skill	79	74	83	71	0.90	0.367
Data Manipulation	79	63	83	34	6.65	0.000*
Data Interpretation	79	76	83	60	4.67	0.000*
Underlying knowledge						
Cat A (moles,calcs,titr)	79	68	83	60	2.08	0.039*
Cat B (acids & bases)	79	72	83	58	4.25	0.000*
Cat C (bal/writ eqns)	79	63	83	42	6.82	0.000*
Cat D (prac knowl)	79	39	83	18	4.26	0.000*
Cat E (units of conc)	79	41	83	32	1.59	0.113

Table 4.53: Students performance in the laboratory examination elements in semester two based on previous chemistry experience

Semester 2 Examination Performance	PC		NC		*t*	*p*
	N	Mean	N	Mean		
Skills						
Technical Skill	76	84	77	79	3.05	0.003*
Observation Skill	76	87	77	82	1.32	0.191
Data Manipulation	76	71	77	50	4.70	0.000*
Data Interpretation	76	77	77	62	4.77	0.000*
Underlying knowledge						
Cat A (moles,calcs,titr)	76	71	77	49	4.69	0.000*
Cat B (acids & bases)	76	91	77	87	1.04	0.298
Cat C (bal/writ eqns)	76	47	77	29	3.33	0.001*
Cat D (prac knowl)	76	57	77	42	4.03	0.000*
Cat E (units of conc)	76	68	77	60	1.55	0.124

Table 4.54: Students performance in the laboratory examination elements in semester one based on gender

Semester1 Examination Performance	Male		Female		*t*	*p*
	N	Mean	N	Mean		
Skills						
Technical Skill	74	76	98	74	0.85	0.396
Observation Skill	74	74	98	71	1.19	0.237
Data Manipulation	74	52	98	43	1.94	0.054
Data Interpretation	74	71	98	65	1.78	0.077
Underlying knowledge						
Cat A (moles,calcs,titr)	74	67	98	61	1.72	0.087
Cat B (acids & bases)	74	67	98	61	1.78	0.077
Cat C (bal/writ eqns)	74	54	98	50	0.95	0.345
Cat D (prac knowl)	74	27	98	27	0.10	0.920
Cat E (units of conc)	74	38	98	34	0.64	0.522

Table 4.55: Students performance in the laboratory examination elements in semester two based on gender

Semester 2 Examination Performance	Male		Female		*t*	*p*
	N	Mean	N	Mean		
Skills						
Technical Skill	68	81	93	81	0.10	0.922
Observation Skill	68	83	93	85	0.57	0.571
Data Manipulation	68	61	93	61	0.11	0.912
Data Interpretation	68	72	93	67	1.42	0.158
Underlying knowledge						
Cat A (moles,calcs,titr)	68	61	93	60	0.35	0.730
Cat B (acids & bases)	68	87	93	90	0.80	0.424
Cat C (bal/writ eqns)	68	37	93	38	0.35	0.726
Cat D (prac knowl)	68	55	93	44	2.81	0.006*
Cat E (units of conc)	68	70	93	60	1.91	0.058

In summary, students completed two laboratory examinations, one in each semester. The questions asked focused on skills and chemical knowledge and understanding. In both semesters, students scored highest in technical and observations skills. They struggled most with data manipulation. It is observed that for all of these categories, they performed better in the second semester than in the first, and this was particularly evident for 'data manipulation' which rose from an average of 47% to 61%. With respect to the 'knowledge and understanding' analysis, students performed best on questions relating to acids and bases in both semesters, and they tended to find balancing and writing reaction equations the most difficult part. However, students' general performance in the underlying knowledge categories improved in the second semester. They scored better in categories relating to their understanding of acids and bases, practical knowledge and units of concentration. However, there were significant decreases observed for their understanding of moles, calculations, titrations and writing reaction equations.

Gender difference had little impact on student performance, the only significant variance observed related to underlying practical knowledge in the second semester, all other grades received comparable. However, previous chemistry background experience has consistently been shown to be a major influence on students' performance. In semester one and two, observational skills is the only skill that both have scored similar marks. Equally, in both semesters there was no difference regarding students' knowledge of units of concentration, and in the second semester, comparable marks were recorded for knowledge of 'acids, bases and pH'. In all of the other categories, PC students demonstrated better performance than NC students.

Overall it appears that students have found experiments and questions that involve data manipulation, calculations, and writing reaction equations the most difficult elements of the laboratories. Gender difference appears to have little or no influence in students' performance in the laboratories. However the study of chemistry prior to coming to university is a significant factor in student performance in the laboratory module even at the end of the first year.

4.4.3 Comparison of students' laboratory examination performance with the other assessment formats used in the laboratories

In an effort to determine how well the assessment of different elements (e.g. skills, understanding etc) reflect the actual independent determination of these skills in a laboratory examination a comparison of students' performance in the laboratory examinations is made with their performance in the other laboratory assessment formats. The comparison is made to determine whether the laboratory examination assessments reflect the tutor marking during the laboratories. Students' grades for all of the assessment sections were standardised out of 100 per cent and Pearson Correlations were used to determine if any significant correlations existed between student performances in the different assessment formats. In Table 4.56 and Table 4.57, the results from the correlations are presented.

This analysis is an attempt to compare tutor marking with the independent laboratory examination, in order to check if the marks awarded by the tutors reflect those awarded in the examination. It must be noted however, that in most cases the correlations made are not exactly comparing like with like e.g. in the laboratory sessions students were awarded marks for their understanding of the laboratory experiment being carried out, there is no direct comparison for this mark in the laboratory examination although it could be expected that there would be a correlation between the understanding mark in the laboratory and the 'underlying knowledge' categories in the laboratory examinations. It would perhaps also be expected that marks awarded for pre-laboratories would correlate with the 'underlying knowledge' categories in the examination as well. It may also be expected that marks awarded for data manipulation and data interpretation would reflect marks awarded for the laboratory journal and it would certainly be expected that the skill marks students achieved during the laboratories would reflect the skill marks awarded in the laboratory examinations.

In Table 4.56, the correlations between the first semester laboratory examination and first year laboratory marks are given. It is noted that the pre-laboratory marks and laboratory questioning marks do correlate with most of the underlying knowledge categories, with the exception being category D, which relates to students underlying practical knowledge. The laboratory journal is shown to correlate with students' data manipulation and data interpretation grades as would be expected. It also is noted to correlate with three of the underlying knowledge categories (A, B &C). Strangely, there are no correlations observed between the skill mark awarded in the laboratory examination and the skill mark awarded for the laboratories.

In the second semester, fewer correlations were observed (Table 4.57). It is noted that the pre-laboratory grades once again correlate with the 'underlying knowledge' categories and also correlates with students technical and observation skills and indeed with the marks awarded for data manipulation and data interpretation. The laboratory questioning grade only correlates with one of the underlying knowledge categories (Category A – moles, calculations and titrations). The journal mark in the second semester is no longer shown to correlate with students' data manipulation and data interpretation grades and there are no correlations observed between the skill mark awarded during the examination and that awarded for the laboratories.

Though the overall laboratory mark achieved was similar to the mark awarded for the laboratory examination, this analysis suggests that there are differences noted between the categories that marks are being awarded for in the laboratory examination and during the laboratories, particularly in the second semester. Some of the differences may be due to examination day pressures that may not be present during a normal laboratory session however, it is doubtful that these would explain all of the observations. Additional possible explanations could be that: tutors were not able to effectively monitor students' skills during the laboratory; in the laboratory examination, the skill laboratory marks were awarded for students being able to set up and operate laboratory equipment During the laboratory sessions' students may have copied other students' experimental set-ups or received help from a colleague, which tutors may not have observed. Some tutors may not have implemented the assessment procedure as intended i.e. some may have given general marks for all categories based on students overall performance or some may have awarded data manipulation marks for questioning as opposed to the journal. Even though this analysis does not directly compare like with like it does show some unexpected differences which raised questions regarding the validity of the tutor marking and highlights and are that needs further analysis in future implementations.

Table 4.56 Correlation of students performance in the laboratory examination and 'during' laboratory assessment formats (Semester 1)

Assessment	Statistics	Pre-labs	Questioning	Journal	Skill Mark
Technical Skill	Pearson	0.167(*)	0.180(*)	0.114	0.113
	Sig.	0.028	0.018	0.135	0.141
	N	172	172	172	172
Observation Skill	Pearson	0.263(**)	0.220(**)	0.148	0.111
	Sig.	0.000	0.004	0.052	0.146
	N	172	172	172	172
Data Manipulation	Pearson	0.233(**)	0.265(**)	0.162(*)	0.064
	Sig.	0.002	0.000	0.034	0.408
	N	172	172	172	172
Data Interpretations	Pearson	0.365(**)	0.352(**)	0.324(**)	0.182(*)
	Sig.	0.000	0.000	0.000	0.017
	N	172	172	172	172
Cat A	Pearson	0.282(**)	0.255(**)	0.182(*)	0.081
	Sig.	0.000	0.001	0.017	0.289
	N	172	172	172	172
Cat B	Pearson	0.349(**)	0.348(**)	0.273(**)	0.186(*)
	Sig.	0.000	0.000	0.000	0.015
	N	172	172	172	172
Cat C	Pearson	0.386(**)	0.415(**)	.365(**)	0.169(*)
	Sig.	0.000	0.000	0.000	0.026
	N	172	172	172	172
Cat D	Pearson	0.161(*)	0.061	0.059	-0.060
	Sig.	0.034	0.425	0.439	0.433
	N	172	172	172	172
Cat E	Pearson	0.151(*)	0.224(**)	0.211(**)	0.132
	Sig.	0.048	0.003	0.005	0.085
	N	172	172	172	172

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

Table 4.57 Correlation of students performance in the laboratory examination and 'during' laboratory assessment formats (Semester 2)

Assessment	Statistics	Pre-Lab	Questioning	Journal	Skill Mark
Technical Skill	Pearson	0.307(**)	0.133	0.221(**)	0.103
	Sig.	0.000	0.093	0.005	0.193
	N	161	161	161	161
Observation Skill	Pearson	0.249(**)	0.140	0.221(**)	0.111
	Sig.	0.001	0.076	0.005	0.162
	N	161	161	161	161
Data Manipulation	Pearson	0.248(**)	0.198(*)	0.099	0.130
	Sig.	0.001	0.012	0.212	0.099
	N	161	161	161	161
Data Interpretations	Pearson	0.218(**)	0.156(*)	0.089	0.077
	Sig.	0.005	0.048	0.263	0.332
	N	161	161	161	161
Cat A	Pearson	0.268(**)	0.195(*)	0.107	0.116
	Sig.	0.001	0.013	0.179	0.143
	N	161	161	161	161
Cat B	Pearson	0.274(**)	0.136	0.226(**)	0.131
	Sig.	0.000	0.085	0.004	0.098
	N	161	161	161	161
Cat C	Pearson	0.238(**)	0.150	0.122	0.077
	Sig.	0.002	0.058	0.123	0.330
	N	161	161	161	161
Cat D	Pearson	0.333(**)	0.241(**)	0.126	0.153
	Sig.	0.000	0.002	0.111	0.053
	N	161	161	161	161
Cat E	Pearson	0.204(**)	0.253(**)	0.042	0.093
	Sig.	0.009	0.001	0.599	0.240
	N	161	161	161	161

** Correlation is significant at the 0.01 level (2-tailed).
* Correlation is significant at the 0.05 level (2-tailed).

In summary, in this work, four aims for laboratories were identified; to develop and provide experience of the following: (1) skills, (2) appropriate assessment, (3) positive learning environment and (4) knowledge and understanding (Table 3.4). For each of these aims, key elements to be developed and or included have been highlighted. In Chapter 3, the actions chosen to achieve these key elements were discussed. In Chapter 4, an evaluation of data relating to student and tutor opinion and regarding students' performance in the laboratories has been presented in order to determine whether the aims were achieved and to highlight any issues that may need to be addressed in future work.

The overall analysis indicates that students' experience of the laboratories improved as the year progressed. Students became more motivated, confident and challenged by the laboratories as they progressed. In the first semester, students built up a positive learning relationship with the tutors and felt that the questioning aspect of the assessment system encouraged them to think and perform better as the semester progressed. Students were also mostly confident regarding the skills abilities, particularly in relation to technical skills and making observations. However, it did take students some time to settle into the module; indeed in the first semester only half of the students enjoyed the laboratories. There are indications from tutors and students that both felt under some time pressures in the first semester. Students felt that they had too little time to complete experiments and tutors found it difficult to implement some of the assessment. There appears to be a combination of factors that could have led to these time pressures. Tutors have noted that students didn't come into the laboratories prepared enough and some of the tasks required in the experiments were perhaps too long and could have been re-ordered. In addition, students didn't feel very confident after completing the pre-laboratories, which could suggest they didn't engage with them or that the pre-laboratory tasks need to be modified to better suit the needs of the students. As mentioned students experience in the 2nd semester improved. Students were more engaged with the laboratories and relied less on tutors. Some have indicated that though they found the second semester more difficult, particularly in relation to data manipulation and writing laboratory reports, they found the experiments more interesting. Students appeared to be under slightly less time pressures in the second semester, though they did note that overcrowding in fumehoods and missing equipment was a source of frustration which added to time pressures. Tutors also appeared better able to implement the assessment elements in the second semester though they still found it difficult to correct the laboratory journal in the laboratory time. As a result many opted to collect the laboratory reports. The provision of feedback appears to be one area that needs future consideration. Tutors felt they could not provide it within the time and some students noted they did not receive appropriate feedback. This could be linked to the time constraints but may also indicate that better training in this area needs to be included in the future.

Students have had the opportunity to apply the knowledge and skills they learned to a real life application. As with students' confidence, their performance in the second semester improved, even though they found the laboratories more challenging. Gender and previous chemistry knowledge had an influence on students' experience within the laboratory. This was particularly evident in relation to chemistry background. Still, at the end of the module NC students were less confidence and didn't perform as well as PC students.

Overall the laboratory implementation has been a positive learning experience for the students. It is suggested that through the actions introduced, students did gain the opportunities to experience and develop all of the key elements highlighted. Students did take time to settle into the laboratory system but their enjoyment increased as the module progressed. There were some concerns regarding the level of preparation on behalf of the students and provision of appropriate feedback by the tutors which need to be addressed for future implementations. However, ultimately this work proposes a framework to which the outlined aims of laboratories can be achieved. It is suggested that through this, increased motivation and engagement can be realised. Students can be encouraged to think, reflect and apply the laboratory skills that they have been taught. It is suggested that with some modifications and improvements, the actions suggested in this implementation can be applied to all stages of undergraduate chemistry and indeed many aspects can be applied to second level and hopefully through which the laboratory will be used to develop appropriate skills.

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[1] Royal Society of Chemistry, Undergraduate Skills Record, [Online: http://www.rsc.org/Education/HEstudents/usr/index.asp]

Conclusion

In the introduction to this study, it was noted that student learning is influenced by many factors, which can be loosely grouped under two headings, (a) learner considerations and (b) teaching considerations. This study has investigated both of these groupings. The first part of the study focused on learner considerations where student interaction with learning supports and student profiles as they progress through university were generated and compared to academic achievement. In the second part of this study, teaching considerations were examined through the introduction of a chemistry laboratory module. Students' experiences of the module and academic performance in the various assessment elements used were evaluated. Additionally, the laboratory module was evaluated in relation to the aims it intended to achieve. In the introduction, research questions relating to both parts of this study were outlined. In this chapter, concluding findings relating to these research questions are given.

The first part of the study attempted to answer two main questions as follows:

a. Do students interact with learning supports when provided and if so is there any correlation between student interaction and academic performance?

In the pilot study, it was noted that even though learning supports were made available to students, they tended not to use them. It was observed that students' interaction with learning supports decreased during the relevant modules and that many students only sought to make use of the learning supports provided in the 'study' and 'examination' weeks. It was clear that students were not interacting with the learning supports during the module. Student interaction with the VLE learning support was shown to positively correlate with their academic achievement. Students who accessed more VLE resources received higher grades. It was also noted that these students also performed better in other components of the first year chemistry module that did not have a VLE learning support. It is not suggested that the provision of learning supports directly lead to increased learning but that these findings indicate that the more conscientious student will use learning supports available even if they do not require them and equally, students who may need additional support in their studies do not take advantage of the supports available.

b. What is the profile of the first year students; how does the profile differ between the successful and the non-successful student? Is it possible to identify the key factors that impact on 'successes' in terms of examination performance? Finally, how does the profile of the first year student change as they progress into the next year of study?

Students indicated predominately intrinsic motivations for attending university. They highlighted a want to develop knowledge and skills and to study interesting and stimulating courses. Students were confident in their preparedness for university study particularly in relation to ICT, study skills, and willingness to engage with teaching staff. Students noted that they intended to achieve honours grades in their first year and to study up to 11 hours each week. Students also indicated a tendency towards deep and strategic approaches compared to a surface approach to learning when they start their university studies. However, students' responses to the learning responsibility statements were less positive. On entry to university, there are issues regarding students' learning skills. They note that they lack confidence in being able to evaluate their learning at university, to work independently without direction from a teacher, to plan their study time and to initiate their own studies.

Students at the end of their first year of university study are mostly positive towards their first year experience. They believed that they became more independent and self-confident and that they learned knowledge and skills they could use in future careers. Students were still confident regarding their ICT and study skills and they indicated that they tended to adopt deep and strategic approaches over surface approaches to learning. However, though student responses are still positive there are changes observed between their profile when entering university and that at the end of their first year of study. It is noted in the majority of cases there is a significant decrease in students' initial responses regarding their perceived learning skills and their wish to study interesting and stimulating courses, compared to those expressed at the end of the year. Overall, there appears to be a mismatch between students' initial expectations of university and their experience. It appears at the end of first year, students are less willing to ask for help when needed and they lack confidence in their ability to work independently and self-evaluate their learning. Their study intentions have also changed, with fewer students are aiming for honour grades and more students are content with a pass grade. There were changes in students' approaches to learning. Data showed that students became less deep, less strategic and more surface in their approach to learning compared to when they started university. Analysis of students' interaction with the learning supports showed similar trends to those found in the pilot study. Students attended less lectures and tutorials in the second semester of their studies. They appeared to have disengaged with their courses as the year progressed.

The profile of students at the end of second year appears to mirror the profile noted at the end of their first year of study. Indeed there were very few changes observed. Students were still mostly positive towards their courses but concerns regarding their ability to monitor their study progress and interact with academic staff still persisted at the end of second year. The most prominent change at the end of second year, related to students' approaches to learning. There was a significant decrease observed in the deep approach and a significant increase seen in students' tendencies towards a surface approach to learning. The similarities between the profile generated at the end of year one and the end of year two suggests that the patterns students adopted towards their first year of study persisted in second year. This highlights the need to address any factors that may be detrimental to student learning (such as the learning responsibility concerns) early in first year of students' studies.

The analysis of the pilot study highlighted a positive correlation between students' interaction with learning supports and examination performance. Similar correlations were made between student responses regarding their experiences of first year undergraduate chemistry. There were positive correlations observed between students who were happy they attended university, felt they studied interesting courses, who felt they developed knowledge and skills and the examination grades they achieved. It was also noted that students who indicated that they took responsibility for their learning, initiated their own study, worked independently and planned their study to meet deadlines achieved better grades than those who didn't. It has been mentioned previously that in all of the profiles generated, some students have indicated difficulties towards these learning responsibilities; this is of concern especially since these learning responsibilities have been positively correlated with student academic performance.

In the second part of this study teaching considerations were examined through the introduction of a chemistry laboratory module. Specifically three main questions were addressed as has been outlined in the Introduction. Summary conclusions arising from each question is now given.

1. *Can a broad range of skills (including technical, communication, observation, data manipulation, data interpretation etc.) and underlying chemical knowledge be taught through chemistry laboratories?*

In this study, it was deemed important that students would be taught a variety of skills through the laboratory module. These skills included technical, communication, recording and observation skills, data manipulation and interpretation and formulation of experimental processes. It was also intended that in addition to skills, students would also learn relevant chemical knowledge through the laboratories. The data indicates that students' confidence in relation to the skills outlined had increased by the end of the module. It was shown that female students were more confident in their recording skills and less confident in their communication skills compared to male students. PC students were more confident than NC students in relation to many of the skills evaluated including data manipulation, data interpretation and formulation of the experimental process. Students also indicated that they liked and learned from each experiment completed. In the second semester students noted increased confidence in their abilities which was reflected by an improvement in both their skills and underlying knowledge grades

2. *Can appropriate assessment be used to evaluate all aspects of chemistry laboratories and encourage student learning?*

In the introduction it was noted that assessment can influence the quality of student learning. In this study a wide variety of assessment formats were used to reward students for all aspects of their laboratory work and also to place a value on all of the work completed in the laboratory. Students generally liked the assessment formats used and felt that they allowed them to demonstrate their abilities. They noted the laboratory reports and the laboratory journal were their favourite assessment formats. They also indicated a high preference towards these formats in addition to the pre-laboratories and the laboratory examinations in terms of allowing them to demonstrate their abilities. Tutor questioning was least liked by students though the majority indicated that this assessment format allowed them to demonstrate their abilities. Students also noted that interaction with the tutors, while being assessed, encouraged them to do better in subsequent laboratories.

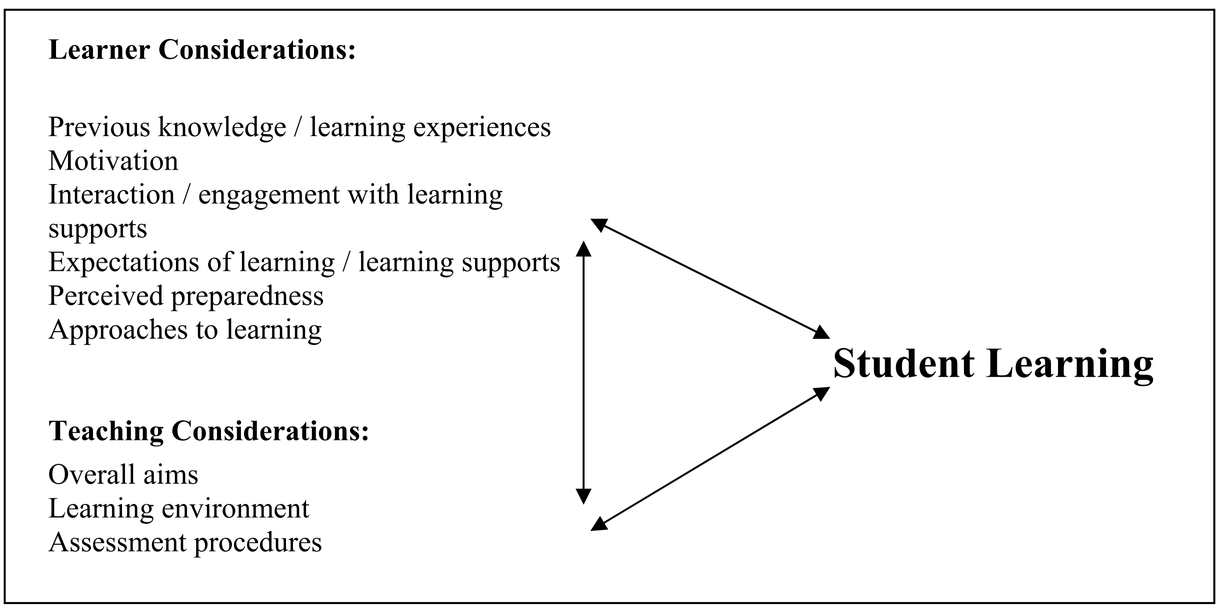
There were some difficulties implementing the assessment system. Tutors noted that they found it difficult to assess all aspects of the laboratories within the given time period, however this was less of an issue in the second semester when the tutor-student ratio was reduced and tutors became more comfortable with the assessment system. It was noted that approximately one fifth of students did not feel that the feedback they received was appropriate regarding their performance and understanding. It was further noted that, though the overall marks awarded for the laboratory were comparable to those awarded for the laboratory examinations, there were few correlations between the assessment marks awarded during the laboratories and those awarded during the examinations e.g. there was no correlation between the skill marks awarded during the laboratories and those awarded in the laboratory examinations. It is suggested that these issues need further investigation and need to be addressed in future implementations.

3. *Can a learning environment that encourages student engagement and interaction with undergraduate chemistry laboratories be introduced with a large heterogeneous group of students?*

It has been previously noted that the design and implementation of the learning environment can influence student learning. Equally, it was mentioned that student interaction with learning environments can affect the quality of student learning. In this study, a 'variety of experiments', 'pre-laboratories', a 'variety of assessment' and 'small group teaching' were incorporated to help create a positive learning environment. Students noted that though they found the laboratories challenging they learned from the experience. They noted that they built up good rapports with their respective tutors, which encouraged them to do better in their subsequent laboratories. Students also liked the different experiments used in the laboratories. They noted that they learned from both closed and more open experiments. They further noted that the Selggog Abbey experiment allowed them to place their learning in a relevant context. Students did take time to adjust to the laboratory system, however as the module progressed they became more confident, more motivated and more independent in their laboratory studies.

In the introduction to this study, 'student learning' was identified as the key focus of education. A list of factors that contribute to the quality of student learning was noted. In this work, both the student contributing factors and teacher contributing factors were investigated in relation to the generation of student profiles as they progress through university and through the introduction of an undergraduate chemistry laboratory. From this study it is clear that these contributing factors towards student learning are not mutually exclusive, in fact they are interconnected, e.g. the approach that students adopt towards their learning is a factor in the quality of their learning but the approach and thus the learning is also influenced by the learning environment. It is suggested that Figure 1 noted in the Introduction to this study should be modified to show the inter-relationships between the factors that influence student learning (See Figure 5.1).

Figure 5.1 Factors that influence student learning



The key findings from this study are that:

- There appear to be some mismatches between students' initial motivations, preparedness and expectations of university study and their experience in a first year undergraduate chemistry course.

- Students have difficulties taking responsibility for their learning, working independently and evaluating their learning during their undergraduate studies. These difficulties, which are evident on entry to university, increase by the end of the first academic year and persist into the second academic year. It has been shown that these factors positively correlate with academic performance in chemistry and thus it is important that any difficulties in respect to these are addressed early in students' university careers.

- A variety of assessment formats can be used in the undergraduate chemistry laboratory to reward students for all aspects of their work and to encourage student interaction with the learning support.

- A variety of laboratory instructional methods can provide students the opportunity to develop and experience the skills and knowledge outlined in the aims of laboratories proposed in this study.

- Small group teaching (SGT) can be used to provide a positive learning environment for large heterogeneous groups of students in the chemistry undergraduate laboratory. SGT is an essential component of this study and through it the implementation of the laboratory module introduced was made possible.

Based on the findings of this study, three main recommendations are made to enhance student learning experience in undergraduate chemistry studies, as follows:

  - The research tools used to investigate student profiles can be used to identify at risk students very soon after entry to university. This information can be used to 'get to

- While it is recognised that most of the first year undergraduate modules cover fundamental concepts in chemistry, students do not always see the relevance of the basic concepts to their chosen careers. Therefore, the undergraduate chemistry content needs to be made ‘appear’ more relevant to students, e.g. by including context and applications.

- The specific actions introduced into the chemistry laboratories have been shown to be effective in terms of skills development, creating a positive learning environment, using assessment to promote learning and engage students and in teaching chemistry content. It is recommended that they be maintained. Additionally, they need to be built upon and integrated throughout an entire degree course to develop skills necessary for graduate employment. It is easily envisaged that the actions implemented within the chemistry laboratory can also be applied in other laboratory courses such as Biology and Physics.

In summary, this study identifies a profile of students as they progress through the early years of their undergraduate studies. It highlights factors that are linked to student success. The study also proposes a framework for undergraduate chemistry laboratories. It suggests four aims of laboratories (skills, appropriate assessments, positive learning environment and underlying knowledge) and the key elements related to each of these aims that laboratories should give students the opportunity to develop and experience. The study proposes actions such as SGT that allow for the successful implementation of the module. There are elements of this study that need further investigation and improvement such as provision of appropriate feedback, assessment implementation, and experimental design. It is suggested that a further study needs to be carried out to determine whether the learning outcomes for each individual experiment satisfy the overall aims of the laboratory proposed and whether these learning outcomes are achieved through the present experimental structure.

Appendix:

Research Tools

ASSIST INVENTORY – All Phases (1,2,3)

Approaches and Study Skills Inventory for Students

(Short version)

This Survey is being used for Postgraduate Research investigating the attitudes of students towards learning in the context of learning Chemistry. It is not for academic assessment. All answers are confidential and student number is only required to match responses later in the semester.
Thank you for completing this and helping us in our research.

PLEASE COMPLETE THIS SURVEY IN RELATION TO YOUR UNIVERSITY CHEMISTRY EXPERIENCE

Please respond truthfully, so that your answers will **accurately** describe your **actual** ways of studying, and work your way through the questionnaire quite **quickly.**

Background information: Name _____________ Date _______________

Student number ____________ Age _____ Sex M/F

University _________________ Faculty or School ____________________

Course ____________________ Year of study _______

A. What is learning?

When you think about the term 'LEARNING " what does it mean to you?

Consider each of these statements carefully; and rate them in terms of how close they are to ***your own*** *way of thinking about it.*

	Very close	*Quite close*	*Not so close*	*Rather different*	*Very different*
a. Making sure you remember things well.	5	4	3	2	1
b. Developing as a person.	5	4	3	2	1
c. Building up knowledge by acquiring facts and information.	5	4	3	2	1
d. Being able to use the information you've acquired.	5	4	3	2	1
e. Understanding new material for yourself.	5	4	3	2	1
f. Seeing things in a different and more meaningful way.	5	4	3	2	1

Please Turn Over

B. Approaches to studying

The next part of this questionnaire asks you to indicate your relative agreement or disagreement with comments about studying again made by other students. Please work through the comments, giving your **immediate** response. In deciding your answers, think in terms of **all chemistry courses.** It is also very important that you answer **all** the questions: check you have.

5 means agree (a) 4 = *agree somewhat* (b) 2 = *disagree somewhat* (*c*) 1 = *disagree*(*d*).
Try not to use 3 = *unsure* (e), *unless you really have to, or if it cannot apply to you or your course.*

	a	b	c	d	e
1. I manage to find conditions for studying which allow me to get on with my own work easily.	5	4	3	2	1
2. When working on an assignment, I'm keeping in mind how best to impress the marker.	5	4	3	2	1
3. Often I find myself wondering whether the work I am doing here is really worthwhile.	5	4	3	2	1
4. I usually set out to understand for myself the meaning of what we have to learn.	5	4	3	2	1
5. I organise my study time carefully to make the best use of it.	5	4	3	2	1
6. I find I have to concentrate on just memorising a good deal of what I have to learn.	5	4	3	2	1
7. I go over the work I've done carefully to check the reasoning and that it makes sense.	5	4	3	2	1
8. Often I feel I'm drowning in the sheer amount of material we're having to cope with.	5	4	3	2	1
9. I look at the evidence carefully and try to reach my own conclusion about what I'm studying.	5	4	3	2	1
!0. It's important for me to feel that I'm doing as well as I really can on the courses here.	5	4	3	2	1
11. I try to relate ideas I come across to those in other topics or other courses whenever possible.	5	4	3	2	1
12. I tend to read very little beyond what is actually required to pass.	5	4	3	2	1
13. Regularly I find myself thinking about ideas from lectures when I'm doing other things.	5	4	3	2	1
14. I think I'm quite systematic and organised when it comes to revising for exams.	5	4	3	2	1
15. I look carefully at tutors ' comments on course work to see how to get higher marks next time.	5	4	3	2	1
16. There's not much of the work here that I find interesting or relevant.	5	4	3	2	1
17. When I read an article or book, I try to find out for myself exactly what the author means.	5	4	3	2	1
18. I'm pretty good at getting down to work whenever I need to.	5	4	3	2	1
19. Much of what I'm studying makes little sense: it's like unrelated bits and pieces.	5	4	3	2	1
20. I think about what I want to get out of this course to keep my studying well focused.	5	4	3	2	1
21. When I'm working on a new topic, I try to see in my own mind how all the ideas fit together.	5	4	3	2	1
22 I often worry about whether I'll ever be able to cope with the work properly.	5	4	3	2	1
23. Often I find myself questioning things I hear in lectures or read in books.	5	4	3	2	1
24. I feel that I'm getting on well, and this helps me put more effort into the work.	5	4	3	2	1
25. I concentrate on learning just those bits of information I have to know to pass.	5	4	3	2	1
26. I find that studying academic topics can be quite exciting at times.	5	4	3	2	1
27. I'm good at following up some of the reading suggested by lecturers or tutors.	5	4	3	2	1
28. I keep in mind who is going to mark an assignment and what they're likely to be looking for.	5	4	3	2	1
29. When I look back, I sometimes wonder why I ever decided to come here.	5	4	3	2	1
30. When I am reading, I stop from time to time to reflect on what I am trying to learn from it.	5	4	3	2	1
31. I work steadily through the term or semester, rather than leave it all until the last minute.	5	4	3	2	1
32. I'm not really sure what's important in lectures so I try to get down all I can.	5	4	3	2	1

Please Turn Over

	a	b	c	d	e
33. Ideas in course books or articles often set me off on long chains of thought of my own.	5	4	3	2	1
34. Before starting work on an assignment or exam question, I think first how best to tackle it.	5	4	3	2	1
35. I often seem to panic if I get behind with my work.	5	4	3	2	1
36. When I read, I examine the details carefully to see how they fit in with what's being said.	5	4	3	2	1
37. I put a lot of effort into studying because I'm determined to do well.	5	4	3	2	1
38. I gear my studying closely to just what seems to be required for assignments and exams.	5	4	3	2	1
39. Some of the ideas I come across on the course I find really gripping.	5	4	3	2	1
40. I usually plan out my week's work in advance, either on paper or in my head.	5	4	3	2	1
41. I keep an eye open for what lecturers seem to think is important and concentrate on that.	5	4	3	2	1
42. I'm not really interested in this course, but I have to take it for other reasons.	5	4	3	2	1
43. Before tackling a problem or assignment, I first try to work out what lies behind it.	5	4	3	2	1
44. I generally make good use of my time during the day.	5	4	3	2	1
45. I often have trouble in making sense of the things I have to remember.	5	4	3	2	1
46. I like to play around with ideas of my own even if they don't get me very far.	5	4	3	2	1
47. When I finish a piece of work, I check it through to see if it really meets the requirements.	5	4	3	2	1
48 Often I lie awake worrying about work I think I won't be able to do.	5	4	3	2	1
49 It's important for me to be able to follow the argument, or to see the reason behind things.	5	4	3	2	1
50. I don't find it at all difficult to motivate myself.	5	4	3	2	1
51. I like to be told precisely what to do in essays or other assignments.	5	4	3	2	1
52. I sometimes get 'hooked' on academic topics and feel I would like to keep on studying them.	5	4	3	2	1

C. Preferences for different types of course and teaching
5 means definitely like (√) 4 = *like to some extent* (√?) 2 = *dislike to some extent* (*x?*) 1 = *definitely dislike* (*x*).
Try <u>not</u> to use 3 = *unsure* (??), *unless you really have to, or if it cannot apply to you or your course.*

	√	√?	??	x?	x
53. lecturers who tell us exactly what to put down in our notes.	5	4	3	2	1
54. lecturers who encourage us to think for ourselves and show us how they themselves think	5	4	3	2	1
55. exams which allow me to show that I've thought about the course material for myself.	5	4	3	2	1
56. exams or tests which need only the material provided in our lecture notes.	5	4	3	2	1
57. courses in which it's made very clear just which books we have to read.	5	4	3	2	1
58. courses where we're encouraged to read around the subject a lot for ourselves.	5	4	3	2	1
59. books which challenge you and provide explanations which go beyond the lectures.	5	4	3	2	1
60. books which give you definite facts and information which can easily be learned.	5	4	3	2	1

Thank you very much for spending time completing this questionnaire: it is much appreciated.

Phase 1 –VLE Survey (V_1)

Student Number:____________________

This Survey is being used for Postgraduate Research investigating the attitudes of students towards learning and the use of Moodle in the context of learning Chemistry. It is not for academic assessment. All answers are confidential and student number is only required to match responses later in the semester.
Thank you for completing this and helping me in my research.

Please Answer All Questions:

1. **Do** you have access to the Internet outside University?
   Yes ☐ *No* ☐

2. **What** do you mostly use computers/Internet for? (Complete in order 1-8 where 1 is your most used option)
   - *E-mail* ☐
   - *Games* ☐
   - *Searching Internet resources* ☐
   - *Using Chat rooms/Forums* ☐
   - *Shopping (Concert tickets, PC's etc)* ☐
   - *Writing Lab reports* ☐
   - *Downloading lecture notes* ☐
   - *Submitting assignments* ☐

3. **How** often do you use e-mail? (tick one)
   - *Several times a day* ☐
   - *Once a day* ☐
   - *Once a week* ☐
   - *Once a month* ☐
   - *Seldom* ☐

4. **Have** you used any of the following computer packages? (Tick all as appropriate)
   - *ISIS Draw* ☐
   - *CALMAT* ☐
   - *Chemdraw* ☐

5. **Do** you search the web for additional material for any of your modules?
   Yes ☐ *No* ☐
   If *Yes* how often do you carry out a search?
   - Daily ☐
   - Once a week ☐
   - Once a month ☐
   - Seldom ☐

6. "I like being directed to websites for topics relating to my course".(**Moodle not included**) (tick one)
   - *Strongly Agree* ☐
   - *Agree* ☐
   - *Sometimes* ☐
   - *Disagree* ☐
   - *Strongly Disagree* ☐

7. **How** do you rate your ICT skills?
   - *Very Good* ☐
   - *Good* ☐
   - *Average* ☐
   - *Poor* ☐

8. **Have** you used Moodle in any of your courses?
   Yes ☐ *No* ☐

If so, list courses: ______________________________
____
____
____

9. **What** have you used Moodle for? (tick all appropriate)
   - *Access to lecture notes* ☐
   - *Quizzes* ☐
   - *Submission of Assignments* ☐
   - *Discussion forums* ☐
   - *Access to tutorial Questions* ☐
   - *Other* ☐

If *Other* Please Specify:
____
____
____
____

10. **What** aspect(s) of Moodle do you like?

____
____
____
____

11. **What** else would you like to be able to use Moodle for?

____
____
____

12. **When** taking notes in lectures: do you prefer (Tick One)

Have lecture notes before hand ☐
Get notes after the lecture ☐
Take down notes in lecture ☐
Whatever the lecturer decides is best ☐

13. **During** semester, how often do you look at your lecture notes?

Everyday ☐
Once a week ☐
Every three weeks ☐
Seldom ☐
Only at exam revision time ☐

14. **What** percentage of chemistry tutorial did you attend last semester?

90-100 % ☐
60-89 % ☐
40-59 % ☐
20-39 % ☐
0-19 % ☐

15. **Do** you have a 3rd level chemistry book?

Yes ☐ *No* ☐

16. **When** studying chemistry, what do you mostly use? (label 1-4 where 1 is your preferred option)

Lecture notes only ☐
Books only ☐
Recommended web resources only ☐
Lecture notes / books ☐
Lecture notes / Internet ☐
Tutorial Q's ☐
Past Exam Papers ☐

17. **What** is your general approach to studying for exams? (tick one)

Do a little bit every week of the semester ☐
Start studying in the middle of the semester ☐
Start studying towards the end of the semester ☐
Leave the majority of your study to the pre exam study period ☐

18. **Have** you any thoughts on how, in general, you would like to study chemistry - any advice to lecturers?

____
____
____
____
____
____
____
____
____
____

Phase 1: VLE Survey (V_2)

Name: ______________________ Student No: ____________________

This Survey is being used for Postgraduate Research investigating the attitudes of students towards learning and the use of Moodle in the context of learning Chemistry. It is not for academic assessment. All answers are confidential and student number is only required to match responses later in the semester.
Thank you for completing this and helping me in my research.

Have you accessed moodle for this course: *Yes*☐ *No*☐ ***If Yes, Proceed to <u>Section A</u>, If No Proceed to <u>Section B</u>***

<u>SECTION A:</u> Please Answer All Questions:

1. **How** often did you access moodle for this course?

   Several times a day ☐
   Once a day ☐
   Once a week ☐
   Once a month ☐
   Seldom ☐

2. **Where** did you access moodle most?

   On campus ☐
   Off Campus ☐

3. **When** did you access moodle most?

   During College hours ☐
   During the evening ☐
   At the weekend ☐

4. **W**hat resources of moodle did you access? (tick all appropriate)

   Lecture Notes ☐
   Tutorial Questions ☐
   Quizzes ☐
   Links to related material ☐
   Chemistry Topics (interesting topics) ☐

5. **Rate** each of these resources on their usefulness (1=very useful, 5=not useful)

   Lecture Notes 1 2 3 4 5
   Tutorial Questions 1 2 3 4 5
   Quizzes 1 2 3 4 5
   Links to related material 1 2 3 4 5
   Chemistry Topics (interesting topics) 1 2 3 4 5

6. **Did** you find moodle easy to use? *Yes* ☐ *No* ☐
   If **No** *Explain*
   ____
   ____
   ____

7. **If** you downloaded lecture notes, **when** did you download them?

   Before Lectures so you could have them in class ☐
   After Lectures ☐
   Sometimes before and sometimes after lectures ☐
   Didn't download them ☐

8. **If** you downloaded tutorial questions, **when** did you download them?

   Before Tutorials ☐
   After Tutorials ☐
   Sometimes before and sometimes after tutorials ☐
   Didn't download them ☐

9. Did having lecture notes on moodle influence your decision about attending lectures?

   No, *I attended the same amount of lectures as I would have if I didn't have the notes on moodle* ☐
   Yes, *I didn't attend as much lectures as I would have if I didn't have the notes on moodle* ☐
   Other, ______________________________
   ____
   ____

10. **Do** you like multiple choice Questions in chemistry?
    Yes ☐ *No:* ☐ *Why?*
    ____
    ____
    ____
    ____

11. **Did** you find the quiz questions difficult?
    Yes ☐ *No* ☐ *I didn't try them* ☐

    If yes, which statement accurately reflects your experience of the quizzes?

    This deterred me from submitting my answers to be corrected ☐
    This stopped me doing future quizzes ☐
    This encouraged me to find out the answers and repeat the quiz ☐

12. **Would** you like to have these quizzes used as continuous assessment quizzes on moodle for this course?
Yes ☐ *No* ☐

13. **Would** you like to have additional weekly problems on moodle with their solutions available in the subsequent week?
Yes ☐ *No* ☐

14. **What** features of moodle do you like?

Access outside standard college hours ☐
Off-Campus Access ☐
Access to lecture notes outside of lecture time ☐
Instant feedback from Quizzes ☐
Other: Please Specify.

____
____
____
____

15. **Is** English your first language? *Yes* ☐ *No* ☐
If **No,** please state your first language: ____________

16. **What** percentage of organic chemistry lectures did you attend this semester?

90-100 % ☐
60-89 % ☐
40-59 % ☐
20-39 % ☐
0-19 % ☐

17. **What** percentage of organic chemistry tutorials did you attend this semester?

90-100 % ☐
60-89 % ☐
40-59 % ☐
20-39 % ☐
0-19 % ☐

18. **Please** add any additional comments on your experience with moodle for this module – any advice for lecturers that may be implemented into your next year moodle modules.

____
____
____
____
____
____

SECTION B: Please Answer All Questions:

1. **Why** did you not access moodle for this module?

I don't like using computers ☐
I didn't have the time ☐
I tried and couldn't log in so I didn't try again ☐
I wasn't interested in using it ☐
Other, Specify ☐

____
____
____

2. **What** percentage of organic chemistry lectures did you attend this semester?

90-100 % ☐
60-89 % ☐
40-59 % ☐
20-39 % ☐
0-19 % ☐

3. **What** percentage of organic chemistry tutorials did you attend this semester?

90-100 % ☐
60-89 % ☐
40-59 % ☐
20-39 % ☐
0-19 % ☐

4. **Is** English your first language? *Yes* ☐ *No* ☐
If no please state your first language: ____________

5. **Please** add any additional comments on your experiences for this module – any advice for lecturers that may be implemented into your next year modules.

____
____
____
____
____
____
____
____

6. Do you intend to download lecture material from moodle over the next two weeks for this module?
Yes ☐ *No* ☐

If Yes, what prevented you from doing so before? -
____
____

Phase 2 Experience Survey 1 (Ex_1)

This Survey is being used for Postgraduate Research investigating students' 1st year experience with chemistry. It is not for academic assessment. All answers are confidential and student number is only required to match responses later in the semester. **Thank you for completing this and helping me in my research.**

Please answer all questions

1. **What influenced you to go to DCU? Please rank in order of preference (where 1=most influenced)**
   Family Career Friends School Interest in subject

2. **Do you have a part time job? Yes No If yes, how many hours per week do you work? ____________**

3. **Are you an active member of a club or society in DCU? Yes No**

4. **Do you think it is easier to succeed in Leaving Cert or in University? L.C. University Same**

5. **Was your current course your 1st choice in CAO? Yes No**
   If not, what preference was your current course? __________

6. **Is your current course what you expected? Yes No**
   Please explain ____
   ____

7. **Do you like your course? Yes No**

8. **What aspects of your course do/don't you like? ______________________________**
   ____
   ____

9. **Do you know what modules you will be studying in the 2nd year of your course? Yes No**

10. **What result do you expect to get in your semester 2 chemistry exam? __________**

11. **What result would you be happy with in your semester 2 chemistry exam? __________**

12. **Do you feel you got the mark you deserved in your semester 1 chemistry exam compared with the effort you put in? Deserved mark Above deserved mark Below deserved mark**

13. **Did you like the chemistry lectures/tutorial you attended?**

Semester 1 Lecture	**Yes**	**No**
Semester 1 Tutorials	**Yes**	**No**
Semester 2 Lecture	**Yes**	**No**
Semester 2 Tutorials	**Yes**	**No**

13a. What % chemistry lectures / tutorials did you attend?

	75-100	**50-74**	**25-49**	**<25**
Semester 1 Lecture				
Semester 1 Tutorials				
Semester 2 Lecture				
Semester 2 Tutorials				

14. **Did you feel you learned from your chemistry lectures/tutorials?**

Semester 1	**Lectures**	**Yes**	**No**	**Semester 2**	**Lectures**	**Yes**	**No**
	Tutorials	**Yes**	**No**		**Tutorials**	**Yes**	**No**

15. **Do you think chemistry lecture/tutorial attendance is related to good performance in chemistry exams?**

Semester 1	**Lectures**	**Yes**	**No**	**Semester 2**	**Lectures**	**Yes**	**No**
	Tutorials	**Yes**	**No**		**Tutorials**	**Yes**	**No**

16. **Did your 1st semester results influence your lecture attendance in 2nd semester? Yes No**
   Explain ____
   ____

17. **If tutorials were part of continuous assessment, would you attend most of them? Yes No**

18. **Do you feel you have committed enough effort to pass your chemistry exam? Yes No**

19. **Do you feel you have committed enough effort to achieve high results in your chemistry exam?**
   Yes No If not, why not? ______________________________
   ____

20. Approximately how many hours each week do you spend studying chemistry this semester
Week 1-6 __________ Week 7-12 ____________ Exam Break ______________

21. In relation to your examinations in college which statement best describes your approach?
  a. **I want to get high results in every year of my course**
  b. **I only care about getting high results in the years that count towards my degree**
  c. **I'm happy if I scrape a pass each year**

22. Do you think doing well in 1st year chemistry will affect your 2nd year chemistry results? Yes No

23. With respect to chemistry lectures please rate the following statements. (1=strongly agree, 5 = strongly disagree)
- **Lectures are interesting** 1 2 3 4 5
- **Lectures provide me with more information than notes** 1 2 3 4 5
- **Lecture attendance is useful in helping me pass chemistry exams** 1 2 3 4 5
- **I need to pay attention in lectures** 1 2 3 4 5
- **I am motivated to read around my lecture material** 1 2 3 4 5

24. Which type of tutorials do you find most beneficial? Please Tick appropriate box

(A) where the answers are written on the board and you don't have to do them
(B) where you are provided with the answers (C) Tutorials where you work out the answers to problems in groups (D) where you are expected to attempt the questions before the tutorial

25. What percentage lectures/tutorials did you attend in other subjects: Please Tick Below

Semester 1	75-100		50-75		25-50		<25		Semester 2	75-100		50-75		25-50		<25	
Lec / Tut	L	T	L	T	L	T	L	T	Lec / Tut	L	T	L	T	L	T	L	T
Biology																	
Maths																	
Physics																	

26. In relation to your first year chemistry, please complete the table below.

	Lecture Attendance	Tutorial Attendance	Lecture notes on web	Weekly use of science clinic	Weekly use of maths clinic	Science clinic at exam time	Maths clinic at exam time	Demonstrators during labs to solve problems
Tick which you have made use of?								
Rank in order of usefulness to you, (1=most important)								
Tick which would you advise to next years 1st yrs?								

27. If you were to advise a student who is starting 1st year next year, how would you advise them to approach college life and their studies? ______________________________

____

____

28. Did having lecture notes on moodle influence your decision about attending lectures?
No*, I attended the same amount of lectures as I would have if I didn't have the notes on moodle*
Yes*, I didn't attend as many lectures as I would have if I didn't have the notes on moodle*
Yes*, I didn't need to go to lectures at all because I had the notes*

Phase 2 Experience Survey (Ex_2)

This Survey is being used for Postgraduate Research investigating students' 1st year experience with chemistry. It is not for academic assessment. All answers are confidential and student number is only required to match responses later in the semester. **Thank you for completing this and helping me in my research.**

Please answer all questions

1. Name: _______________ Student No: ________________ Course: ___________ Date: ________

2. Do you like your course? Yes No

3. What aspects of your course do you like? ______________________________

4. What aspects of your course don't you like? ______________________________

5. Is your current course what you expected? Yes No
Please explain ______________________________

6. How many hours of study do you do outside class each week during 2nd year? ______

7. Please complete the table below in relation to your 2nd year chemistry modules

	Spectroscopy Workshop	Bio-organic & Pharmaceutical	Thermodynamics + Kinetics	Inorganic
What grade are you aiming to get in the following				
What grade would you be happy with in the following				
How many hours of study do you do outside class each week for the respective modules				
Do you feel you have committed enough effort to pass your exam? (Indicate **Yes** or **No**)				
Do you feel you have committed enough effort to achieve high results in your exam? (Indicate **Yes** or **No**)				
Did you like the chemistry lectures you attended? (Indicate **Yes** or **No**)				
What % of lectures/Workshops did you attend?				
Do you feel you learned from the lectures? (Indicate **Yes** or **No**)				

8. Do you think chemistry lecture/tutorial attendance is related to good performance in chemistry exams? Yes No

9. Give reasons for you answer above: ______________________________

10. Indicate the extent to which you agree to the following statements in relation to your university experience.
Please circle your response to each item

		Very Strongly	Fairly Strongly	Somewhat /not sure	Rather Weakly	Very weakly
a	I have developed knowledge and skills that I can use in a career.	5	4	3	2	1
b	I have learned things that will help me to develop as a person and broaden my horizons.	5	4	3	2	1
c	I have an active social life and/or sport in DCU	5	4	3	2	1
d	My 1st year experience has made me more independent and self-confident.	5	4	3	2	1
e	I have studied chemistry in depth by taking interesting and stimulating courses.	5	4	3	2	1
f	I have learned things that might let me help people, and/or make a difference in the world.	5	4	3	2	1
g	I am happy I decided to go to University	5	4	3	2	1
h	I am happy I decided to go this University	5	4	3	2	1

Please Turn Over →

11. Indicate the extent to which you agree to the following statements in relation to your 2nd year chemistry experience:
Please <u>circle</u> your response

		Very Strongly	Fairly Strongly	Somewhat /not sure	Rather Weakly	Very weakly
a	I know what is expected of me academically in university	5	4	3	2	1
b	I have worked independently without much direction from a lecturer	5	4	3	2	1
c	I have initiated my own study activities	5	4	3	2	1
d	I am able to plan my study in a time effective manner to meet all my deadlines	5	4	3	2	1
e	I have taken responsibility for my own learning	5	4	3	2	1
f	I have asked for help from my lecturers/tutors when needed	5	4	3	2	1
g	I am confident about my ability to use a computer	5	4	3	2	1
h	I am comfortable when working in groups	5	4	3	2	1
i	I am confident about my ability to complete written assignments	5	4	3	2	1
j	I feel comfortable asking lecturers questions about material I don't understand	5	4	3	2	1
k	I have evaluated my own progress	5	4	3	2	1
l	I have organised my own life generally	5	4	3	2	1
m	I am confident in planning and making oral presentations	5	4	3	2	1
n	I can use internet and other resources to gain information	5	4	3	2	1

12. With respect to chemistry lectures please rate the following statements. (1=strongly agree, 5 = strongly disagree)

	Spectroscopy Workshop	Bio-organic & Pharmaceutical	Thermodynamics + Kinetics	Inorganic
Lectures are interesting				
Lectures provide me with more information than notes				
Lecture attendance is useful in helping me pass chemistry exams				
I need to pay attention in lectures				
I am motivated to read around my lecture material				

13. Were you aware that your 2nd year results will have an influence on your 3rd year intra placement? Yes No

14. (Yes): Has this had any impact on your motivation to study this year? Yes No
(No): If you had known, would this have had an impact on your motivation to study this year? Yes No
Discuss: ____
____
____

15. Indicate the extent to which you agree to the following statements in relation general expectation of chemistry exams:
Please <u>circle</u> your response

		Very Strongly	Fairly Strongly	Somewhat /not sure	Rather Weakly	Very weakly
a	I am only expected to reproduce what was in the lecture notes	5	4	3	2	1
b	I will have to show I understand what was covered in lectures	5	4	3	2	1
c	I will have to use information I learned in lectures to solve unseen problems	5	4	3	2	1
d	I will have to show that I studied outside of what was in the lecture notes	5	4	3	2	1

THANK YOU ☺

Motivations and Preparedness and Expectations

This Survey is being used for Postgraduate Research investigating students' 1st year experience with chemistry. It is not for academic assessment. All answers are confidential and student number is only required to match responses later in the semester. **Thank you for completing this and helping me in my research.**

Please answer all questions

Background Information:

1. Name: _______________ Student No: ________________ Course: ___________ Date: ________

2. CAO points achieved: _________

3. Was your current course your 1st choice in CAO? Yes No
   If not, what preference no. was your current course? __________ , What was your 1st preference course? _____________

4. What influenced you to go to DCU? Please rank in order of preference (where 1=most influenced)
   Family Career Friends School Interest in subject

5. Do you intend to have a part time job during the academic year? Yes No
   If yes, how many hours per week are you likely to work? ________

6. How many hours of study do you plan to do outside class each week during this year? ______

7. How many hours of study do you plan to do outside class each week for 1st year chemistry? ______

Motives for coming to University

Indicate the extent to which you agree to the following statements in relation to your decision to come to university.

Please circle your response to each item

		Very Strongly	Fairly Strongly	Somewhat /not sure	Rather Weakly	Very weakly
a	I want to develop knowledge and skills I can use in a career.	5	4	3	2	1
b	I hope the things I learn will help me to develop as a person and broaden my horizons.	5	4	3	2	1
c	I'm focused on the opportunities here for an active social life and/or sport.	5	4	3	2	1
d	I hope the whole experience here will make me more independent and self-confident.	5	4	3	2	1
e	Having done well in school, going to university was the natural thing to do.	5	4	3	2	1
f	Coming to university affords me three more years to decide what I really want to do	5	4	3	2	1
g	I want to study the subject in depth by taking interesting and stimulating courses.	5	4	3	2	1
h	All my friends were going to university	5	4	3	2	1
i	I want an opportunity to prove to myself or to other people what I can do.	5	4	3	2	1
J	Progression to university is what others expected of me	5	4	3	2	1
k	I mainly need the qualification to enable me to get a good job when I finish.	5	4	3	2	1
l	I want to learn things which might let me help people, and/or make a difference in the world.	5	4	3	2	1
m	When I look back, I sometimes wonder why I ever decided to come here.	5	4	3	2	1

Please Turn Over →

Preparedness for University
Indicate the extent to which you agree to the following statements in relation to university study: **Please circle your response**

		Very Strongly	Fairly Strongly	Somewhat /not sure	Rather Weakly	Very weakly
a	I know what is expected of me academically in university	5	4	3	2	1
b	I am able to work independently without much direction from a teacher	5	4	3	2	1
c	I am able to initiate my own study activities	5	4	3	2	1
d	I am able to plan my study in a time effective manner to meet all my deadlines	5	4	3	2	1
e	I am able to take responsibility for my own learning	5	4	3	2	1
f	I am willing to ask for help from my lectures/tutors	5	4	3	2	1
g	I am confident about my ability to use a computer	5	4	3	2	1
h	I am comfortable working in groups	5	4	3	2	1
i	I am confident about my ability to complete written assignments	5	4	3	2	1
J	I am willing to participate in class	5	4	3	2	1
k	I am able to evaluate my own progress	5	4	3	2	1
l	I am able to organise my own life generally	5	4	3	2	1
m	I am confident in planning and making oral presentations	5	4	3	2	1
n	I can use internet and other resources to gain information	5	4	3	2	1

Chemistry Background and Expectations

1. What grade did you get in the following Leaving certificate science subjects?

Subject	**Honours**	**Ordinary**	**Didn't do**	**Other Science Subject**	**Level**	**Grade**
Chemistry						
Physics						
Biology						

2. Did you enjoy Leaving Certificate chemistry Yes No Not Applicable
What did/didn't you enjoy about leaving certificate chemistry?

____

____

3. What aspects/topics of chemistry do you hope to cover in your 1st year course?

____

____

4. What grade are you aiming to get in chemistry? ___________
5. What grade would you be happy with in chemistry? ________

6. Indicate the extent to which you agree to the following statements in relation to university study:
Please circle your response

		Very Strongly	Fairly Strongly	Somewhat /not sure	Rather Weakly	Very weakly
a	I am able to handle chemicals in the laboratory	5	4	3	2	1
b	I am able to handle glassware in the laboratory	5	4	3	2	1
c	I am aware of specific hazards relating to chemicals	5	4	3	2	1
d	I am able to measure and observe chemical events and changes	5	4	3	2	1
e	I am able to analyse and evaluate experimental data	5	4	3	2	1
f	I am able to interpret chemical information	5	4	3	2	1
g	I am able to select appropriate techniques and procedure	5	4	3	2	1
h	I can identify errors in chemistry experiments	5	4	3	2	1
i	I am able to maintain good laboratory notes	5	4	3	2	1

Phase 3: 1st Year Experience Survey (Ex_1)

This Survey is being used for Postgraduate Research investigating students' 1st year experience with chemistry. It is not for academic assessment. All answers are confidential and student number is only required to match responses later in the semester. **Thank you for completing this and helping me in my research.**

Please answer all questions

1. Name: ______________ Student No: ______________ Course: __________ Date: ________

2. Do you like your course? Yes No

3. What aspects of your course do you like? ______________________________

4. What aspects of your course don't you like? ______________________________

5. Is your current course what you expected? Yes No
Please explain ______________________________

6. Do you know what modules you will be studying in the 2nd year of your course? Yes No

7. What grade are you aiming to get in chemistry? ________

8. What grade would you be happy with in chemistry? ______

9. How many hours of study do you do outside class each week during this year? ______

10. How many hours of study do you do outside class each week for 1st year chemistry? ______

11. Did you have a part time job during this year of college? Yes No

12. If so, how many hours did you work this year? __________

13. Do you feel you got the mark you deserved in your chemistry continuous assessment?
Deserved mark Above deserved mark Below deserved mark

14. Do you feel you have committed enough effort to pass your chemistry exam? Yes No

15. Do you feel you have committed enough effort to achieve high results in your chemistry exam? Yes No

If not, why not? ______________________________

Indicate the extent to which you agree to the following statements in relation to your decision to come to university.

16. **Please circle your response to each item**

		Very Strongly	Fairly Strongly	Somewhat /not sure	Rather Weakly	Very weakly
a	I have developed knowledge and skills that I can use in a career.	5	4	3	2	1
b	I have learned things that will help me to develop as a person and broaden my horizons.	5	4	3	2	1
c	I have an active social life and/or sport in DCU	5	4	3	2	1
d	My 1st year experience has made me more independent and self-confident.	5	4	3	2	1
e	I have studied chemistry in depth by taking interesting and stimulating courses.	5	4	3	2	1
f	I have learned things that might let me help people, and/or make a difference in the world.	5	4	3	2	1
g	I am happy I decided to go to University	5	4	3	2	1
h	I am happy I decided to go to this University	5	4	3	2	1

17. Indicate the extent to which you agree to the following statements in relation to your 1st year studying chemistry at university: **Please <u>circle</u> your response**

		Very Strongly	Fairly Strongly	Somewhat /not sure	Rather Weakly	Very weakly
a	I know what is expected of me academically in university	5	4	3	2	1
b	I have worked independently without much direction from a teacher	5	4	3	2	1
c	I have initiated my own study activities	5	4	3	2	1
d	I am able to plan my study in a time effective manner to meet all my deadlines	5	4	3	2	1
e	I have taken responsibility for my own learning	5	4	3	2	1
f	I have asked for help from my lecturers/tutors when needed	5	4	3	2	1
g	I am confident about my ability to use a computer	5	4	3	2	1
h	I am comfortable when working in groups	5	4	3	2	1
i	I am confident about my ability to complete written assignments	5	4	3	2	1
J	I feel able to ask my lecturer questions about material I don't understand	5	4	3	2	1
k	I have evaluated my own progress	5	4	3	2	1
l	I have organised my own life generally	5	4	3	2	1
m	I am confident in planning and making oral presentations	5	4	3	2	1
n	I can use internet and other resources to gain information	5	4	3	2	1

18. Did you like the chemistry lectures/tutorial you attended?

Semester 1 Lecture	Yes	No
Semester 1 Tutorials	Yes	No
Semester 2 Lecture	Yes	No
Semester 2 Tutorials	Yes	No

13a. What % chemistry lectures / tutorials did you attend?

	75-100	50-74	25-49	<25
Semester 1 Lecture				
Semester 1 Tutorials				
Semester 2 Lecture				
Semester 2 Tutorials				

19. Did you feel you learned from your chemistry lectures/tutorials?
<u>Semester 1</u> Lectures Yes No <u>Semester 2</u> Lectures Yes No
Tutorials Yes No Tutorials Yes No

20. Do you think chemistry lecture/tutorial attendance is related to good performance in chemistry exams?
<u>Semester 1</u> Lectures Yes No <u>Semester 2</u> Lectures Yes No
Tutorials Yes No Tutorials Yes No

21. Did your continuous assessment results influence your lecture attendance in 2nd semester? Yes No
Explain ____
____

22. In relation to your examinations in college which statement best describes your approach?
a. I want to get high results in every year of my course
b. I only care about getting high results in the years that count towards my degree
c. I'm happy if I scrape a pass each year

23. Do you think doing well in 1st year chemistry will affect your 2nd year chemistry results? Yes No

24. With respect to chemistry lectures please rate the following statements. (1=strongly agree, 5 = strongly disagree)
- Lectures are interesting 1 2 3 4 5
- Lectures provide me with more information than notes 1 2 3 4 5
- Lecture attendance is useful in helping me pass chemistry exams 1 2 3 4 5
- I need to pay attention in lectures 1 2 3 4 5
- I am motivated to read around my lecture material 1 2 3 4 5

25. Which type of tutorials do you find most beneficial? Please Tick appropriate box

(A) where the answers are written on the board and you don't have to do them
(B) where you are provided with the answers (C) Tutorials where you work out the answers to problems in groups (D) where you are expected to attempt the questions before the tutorial

26. What percentage lectures/tutorials did you attend in other subjects: Please Tick Below

Semester 1	75-100		50-75		25-50		<25		Semester 2	75-100		50-75		25-50		<25	
Lec / Tut	L	T	L	T	L	T	L	T	Lec / Tut	L	T	L	T	L	T	L	T
Biology																	
Maths																	
Physics																	

27. In relation to your first year chemistry, please complete the table below.

	Lecture Attendance	Tutorial Attendance	Lecture notes on web	Weekly use of maths clinic	Maths clinic at exam time	Demonstrators during labs to solve problems
Tick which you have made use of?						
Rank in order of usefulness to you, (1=most important)						
Tick which would you advise to next years 1st yrs?						

28. If you were to advise a student who is starting 1st year next year, how would you advise them to approach college life and their studies? ____________________

____

____

29. Indicate the extent to which you agree to the following statements in relation general expectation of chemistry exams: **Please <u>circle</u> your response**

		Very Strongly	Fairly Strongly	Somewhat /not sure	Rather Weakly	Very weakly
a	I am only expected to reproduce what was in the lecture notes	5	4	3	2	1
b	I will have to show I understand what was covered in lectures	5	4	3	2	1
c	I will have to use information I learned in lectures to solve unseen problems	5	4	3	2	1
d	I will have to show that I studied outside of what was in the lecture notes	5	4	3	2	1

Phase 3: Experience Survey 2 (Ex_2)

This Survey is being used for Postgraduate Research investigating students' 1st year experience with chemistry. It is not for academic assessment. All answers are confidential and student number is only required to match responses later in the semester. **Thank you for completing this and helping me in my research.**

Please answer all questions

1. Name: _______________ Student No: ________________ Course: ___________ Date: ________

2. Do you like your course? Yes No

3. What aspects of your course do you like? ______________________________

4. What aspects of your course don't you like? ______________________________

5. Is your current course what you expected? Yes No
Please explain ______________________________

6. Do you have a part time job at present? Yes No

If so, how many hours do you work weekly? _____________

7. How many hours of study do you do outside class each week during 2nd year? ___________________

8. Do you feel you have committed enough effort to pass your 2nd year exams? Yes No

9. Do you feel you have committed enough effort to achieve high results in your 2nd year exams? Yes No

If not, why not? ______________________________

10. Were you aware that your 2nd year results will have an influence on your 3rd year intra placement? Yes No

11. (Yes): Has this had any impact on your motivation to study this year? Yes No
(No): If you had known, would this have had an impact on your motivation to study this year? Yes No
Discuss: ______________________________

12. Please complete the table below in relation to your 2nd year chemistry modules (where applicable):

	Spectroscopy Workshop	Bio-organic & Pharmaceutical	Forensic Workshop	Chemistry Environment/ Thermodynamics + Kinetics	Inorganic
What grade are you aiming to get in the following					
What grade would you be happy with in the following					
How many hours of study do you do outside class each week for the respective modules					
Do you feel you have committed enough effort to pass your exam? (Indicate **Yes** or **No**)					
Do you feel you have committed enough effort to achieve high results in your exam? (Indicate **Yes** or **No**)					
Did you like the chemistry lectures you attended? (Indicate **Yes** or **No**)					
What % of lectures/Workshops did you attend?					
Do you feel you learned from the lectures? (Indicate **Yes** or **No**)					

13. Indicate the extent to which you agree to the following statements in relation to your university experience.
Please circle your response to each item

		Very Strongly	Fairly Strongly	Somewhat /not sure	Rather Weakly	Very weakly
a	I have developed knowledge and skills that I can use in a career.	5	4	3	2	1
b	I have learned things that will help me to develop as a person and broaden my horizons.	5	4	3	2	1
c	I have an active social life and/or sport in DCU	5	4	3	2	1
d	The experience has made me more independent and self-confident.	5	4	3	2	1
e	I have studied chemistry in depth by taking interesting and stimulating courses.	5	4	3	2	1
f	I have learned things that might let me help people, and/or make a difference in the world.	5	4	3	2	1
g	I am happy I decided to go to University	5	4	3	2	1
h	I am happy I decided to go this University	5	4	3	2	1

14. Indicate the extent to which you agree to the following statements in relation to your 2nd year chemistry experience:
Please circle your response to each item

		Very Strongly	Fairly Strongly	Somewhat /not sure	Rather Weakly	Very weakly
a	I know what is expected of me academically in university	5	4	3	2	1
b	I have worked independently without much direction from a lecturer	5	4	3	2	1
c	I have initiated my own study activities	5	4	3	2	1
d	I have planed my study in a time effective manner to meet all my deadlines	5	4	3	2	1
e	I have taken responsibility for my own learning	5	4	3	2	1
f	I have asked for help from my lecturers/tutors when needed	5	4	3	2	1
g	I am confident about my ability to use a computer	5	4	3	2	1
h	I am comfortable when working in groups	5	4	3	2	1
i	I am confident about my ability to complete written assignments	5	4	3	2	1
j	I feel comfortable asking lecturers questions about material I don't understand	5	4	3	2	1
k	I have evaluated my own progress	5	4	3	2	1
l	I have organised my own life generally	5	4	3	2	1
m	I am confident in planning and making oral presentations	5	4	3	2	1
n	I can use internet and other resources to gain information	5	4	3	2	1

15. Indicate the extent to which you agree to the following statements in relation to your 2nd year chemistry experience:
Please circle your response to each item

		Very Strongly	Fairly Strongly	Somewhat /not sure	Rather Weakly	Very weakly
a	**I am able** to work independently without much direction from a lecturer	5	4	3	2	1
b	**I am able** to initiate my own study activities	5	4	3	2	1
c	**I am able** to plan my study in a time effective manner to meet all my deadlines	5	4	3	2	1
d	**I am able** to take responsibility for my own learning	5	4	3	2	1
e	**I am willing** to ask for help from my lecturers/tutors when needed	5	4	3	2	1
f	**I am willing** to participate in class	5	4	3	2	1
g	**I am able** to evaluate my own progress	5	4	3	2	1
h	**I am able** to organise my own life generally	5	4	3	2	1

16. With respect to chemistry lectures please rate the following statements. (1=strongly agree, 5 = strongly disagree)

	Spectroscopy Workshop	Bio-organic & Pharmaceutical	Forensic Workshop	Chemistry Environment/ Thermodynamics + Kinetics	Inorganic
Lectures are interesting					
Lectures provide me with more information than notes					
Lecture attendance is useful in helping me pass chemistry exams					
I need to pay attention in lectures					
I am motivated to read around my lecture material					

17. Do you think chemistry lecture/tutorial attendance is related to good performance in chemistry exams? Yes No

18. Give reasons for you answer above:____

____

19. Indicate the extent to which you agree to the following statements in relation general expectation of chemistry exams:
Please circle your response

		Very Strongly	Fairly Strongly	Somewhat /not sure	Rather Weakly	Very weakly
a	I am only expected to reproduce what was in the lecture notes	5	4	3	2	1
b	I will have to show I understand what was covered in lectures	5	4	3	2	1
c	I will have to use information I learned in lectures to solve unseen problems	5	4	3	2	1
d	I will have to show that I studied outside of what was in the lecture notes	5	4	3	2	1

Thank you for your help with this research

☺

Phase 3: Laboratory Evaluation 1 (Time B)

This survey is being used for Postgraduate Research investigating students' 1st year experience of chemistry laboratories. **It is not for academic assessment.** All answers are **confidential**.

Please answer all questions in relation to your 1st semester chemistry laboratories

1. Did you do leaving certificate chemistry: Yes ☐ No ☐
2. How much time did you spend each week on your pre-lab task? ______________
3. What aspects of chemistry labs **did** you like? ______________________________

4. What aspects of chemistry labs **didn't** you like? ______________________________

5. What books/websites/notes did you use to answer your pre-lab tasks? ______________________________

6. Indicate the extent to which you agree with the following statements in relation to your pre-lab preparation.
Please tick your response to each item

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	Having completed the pre-lab I was confident I understood the chemistry theory relating to the related laboratories					
b	Having completed the pre-lab I was confident about the practical work I would complete in the laboratory					
c	Tutor questioning on the pre-lab encouraged me to do my best in subsequent pre-labs					
d	My marks in the pre-lab reflected the effort I put into them.					
e	I was well prepared for the experiment that I would carry out each week					
f	I was aware of the aim of the experiment before I entered the lab					

7. What could you have done to prepare better for the chemistry laboratories? ______________________________

8. Indicate the extent to which you agree to the following statements in relation to your experience within the labs.
Please tick your response to each item

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	Having a no. of different tasks to complete within the lab encouraged me to complete the entire lab					
b	I liked the problem tasks (generally task 3) at the end of the lab experiments					
c	The initial tasks (tasks 1-2) prepared me to complete the problem tasks (task 3) at the end of the experiment					
d	The problem tasks (tasks 3) made me think about what I was doing in the laboratory					
e	The questions at the end of each experiment made me think about what was covered in the experiment					
f	The lab tutors were approachable and helpful					
g	Even though my tutor was grading me I was comfortable asking him/her questions					
h	The tutors questions made me think about the chemistry I was doing					
i	Answering tutor questions made me confident/clearer about the chemistry I was doing					
j	I did not like talking to my tutor since s/he was assessing me					

PLEASE TURN OVER →→→

9. Indicate the extent to which you agree to the following statements in relation to your overall lab experience.
Please tick your response to each item

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	If I prepared properly for the lab there was enough time to complete the lab experiments					
b	I learned chemistry through the lab experiments					
c	I enjoyed/liked the chemistry labs					
d	I learned lab skills in the chemistry laboratories					
e	Overall I found the chemistry labs challenging but doable					
f	I found the theory of the chemistry in the labs difficult					
g	I found practical calculations difficult					
h	I found the laboratory manual easy to understand					
i	I found the practical part of the lab difficult					
j	I found writing a lab report easy					

10. **Please tick the appropriate boxes** indicating whether you agree or disagree to the statements in relation to the name experiments.

	I liked the experiment/activity		I learned from this experiment/activity		I didn't see the purpose of this experiment/activity	
	Agree	Disagree	Agree	Disagree	Agree	Disagree
1.1 Introduction to fundamentals in the lab						
1.2 What is a mole?						
1.3 Qualitative identification through solubility						
1.4 Identification of unknowns						
1.5 Acids, bases, indicators and pH						
Oral Presentation						
Practical Skills Assessment						
1.6 What concentration is it?						
1.7 Calorimetric determination of enthalpies						
1.8 Devise an experiment						
1.9 Determination of the ideal gas constant						
1.10 Identification of the stoichiometry of a metal-ligand complex						

11. Indicate the extent to which you agree to the following statements
Please tick your response to each item

	A good lab tutor is someone who . . .	Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	tells me all the answers when I ask them					
b	encourages me to think about the lab I'm doing					

12. Which aspects of the laboratories would like changed for 2nd semester labs?

____

____

Complete the following questions in relation to a comparison between physics and chemistry laboratories

13. I found having assessed pre-labs as in chemistry more beneficial than non-assessed pre-labs as in physics
Yes ☐ No ☐ Didn't matter ☐

14. I preferred having general lab tutors as in physics compared to having dedicated/assigned lab tutors as in chemistry
Yes ☐ No ☐ Didn't matter ☐

15. I preferred following/completing worksheets/handouts as in physics to keeping a lab notebook as in chemistry
Yes ☐ No ☐ Didn't matter ☐

THANK YOU! ☺

Phase 3 Tutor Laboratory Survey 1 (Time B)

This survey is being used for Postgraduate Research investigating tutors' experience of chemistry laboratories. All answers are confidential. **Thank you for completing this survey.**

Please answer all questions in relation to your tutoring of chemistry laboratories

Name:______________________________________ Date:________________

1. Indicate the extent to which you agree to the following statements in relation to your opinion of the students' experience of the 1st year chemistry laboratories.

Please tick your response to each item

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	Students responded positively to questioning within the lab					
b	Students put a lot of effort into the pre-labs					
c	Students put effort into understanding the labs					
d	Students general effort increased as the semester progressed					
e	Students enjoyed the laboratory experience					
f	Students were fairly rewarded for the work they out in					
g	Your students did better than the average student					
h	Students without leaving certificate chemistry struggled more than those who had done chemistry before					
i	Students with leaving certificate chemistry put in less effort than those without leaving cert chemistry					

2. Please use the space provided to make additional comments on the above questions if required: ____________

____

____

____

3. Indicate the extent to which you agree to the following statements in relation to your experience of the 1st year chemistry laboratories.

Please tick your response to each item

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	I built up a good relationship with my students					
b	All my students demanded my time equally					
c	It was possible to correct pre-labs during the lab session					
d	It was possible to give student feedback on the pre-labs					
e	It was possible to correct the notebooks within the lab					
f	It was possible to give feedback on the notebooks within the lab					
g	I was able to spend time with students who needed my time					
h	I spread my time equally amongst all of my students					
i	I found it easy to ask students challenging questions					
j	I'd prefer to correct the lab notebook outside of the lab					
k	If I corrected the notebook outside of the lab I would have more time to concentrate on questioning					
l	I prepared for each lab session before entering the lab					

4. Please use the space provided to make additional comments on the above questions if required: ____________

____

____

____

PLEASE TURN OVER →→→

5. Did you enjoy the tutoring experience? Yes ☐ No ☐

Please comment on your answer: ____
____
____
____
____

6. **Please tick the appropriate boxes** indicating whether you agree or disagree to the statements in relation to the name experiments.

	Suitable level for the students		Aims were clear		Manual was clear		Questions in manual were clear	
	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree
1.1 Introduction to fundamentals in the lab								
1.2 What is a mole?								
1.3 Qualitative identification through solubility								
1.4 Identification of unknowns								
1.5 Acids, bases, indicators and pH								
1.6 What concentration is it?								
1.7 Calorimetric determination of enthalpies								
1.8 Devise an experiment								
1.9 Determination of the ideal gas constant								
1.10 Identification of the stoichiometry of a metal-ligand complex								

7. What do you think is the key objective of the re-vamp in the 1st year labs? _______ ____________________
____
____
____

8. What do you think are the key elements that should be present in a 1st year laboratory? __________________
____
____
____

9. Please add any additional comments: ____
____
____
____
____

Phase 3 Tutor Laboratory Survey 1a (Time B)

This survey is being used for Postgraduate Research investigating tutors' experience of tutor training. All answers are confidential. **Thank you for completing this survey.**

Please answer all questions in relation to your tutoring training for chemistry laboratories

Name:_______________________________ Date:_______________

1. Indicate the extent to which you agree to the following statements in relation to the tutor training workshop held at the beginning of the semester.

Please tick your response to each item

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	The training workshop increased my awareness of what was to be expected in labs/tutorials.					
b	The training workshop increased my interest in and enthusiasm for the task of tutoring.					
c	The training workshop increased my awareness of the importance of my role as a tutor.					
d	The training workshop increased my awareness of the importance of empathising with students in my classes.					
e	Overall, I think the training workshop helped to make me a more effective tutor.					
f	Overall, I think the training workshop was relevant to the job I am doing as a tutor.					
g	I think I learned some valuable skills in the training workshop.					

2. What aspects of the workshop do you think helped you in your work as a tutor? (discussion of role of tutor, case studies, communication skills with James Wisdom) ____

____

____

____

3. Indicate the extent to which you agree to the following statements in terms of your preparedness for tutoring within the chemistry laboratory following the pre-semester chemistry training and the weekly pre-lab meetings:

Please tick your response to each item

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	I felt prepared in relation to the chemistry being covered in the laboratory sessions					
b	I felt I was prepared in relation to the practical activity that was being coved in the laboratory					
c	I knew what was expected of me within the labs					
d	I felt I was prepared to interacting with students					
e	I understood how I was going to assess the students pre-labs					
f	I understood how I was going to assess the students understanding of the experiment					
g	I understood how I was going to assess the students notebook					
h	If I was unsure about any aspect I was able to ask someone for advice/help					
i	It was helpful to be able to do the experiments on the Wednesday before the laboratory session (exp 1-6)					
j	The handouts of the experiments were useful					

Phase 3: Laboratory Evaluation 2 (Time C)

This survey is being used for Postgraduate Research investigating students' 1st year experience of chemistry laboratories. **It is not for academic assessment.** All answers are **confidential**.

Please answer all questions in relation to your 2nd semester chemistry laboratories

1. How much time did you spend each week on your 2nd semester pre-lab tasks? _______________
3. What aspects of 2nd semester chemistry labs **did** you like? _______________

4. What aspects of 2nd semester chemistry labs **didn't** you like? _______________

5. What books/websites/notes did you use to answer your 2nd semester pre-lab tasks? _______________

6. Indicate the extent to which you agree with the following statements in relation to your pre-lab preparation.
Please tick your response to each item

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	Having completed the pre-lab I was confident I understood the chemistry theory relating to the related laboratories					
b	Having completed the pre-lab I was confident about the practical work I would complete in the laboratory					
c	Tutor questioning on the pre-lab encouraged me to do my best in subsequent pre-labs					
d	My marks in the pre-lab reflected the effort I put into them.					
e	I was well prepared for the experiment that I would carry out each week					
f	I was aware of the aim of the experiment before I entered the lab					

7. What could you have done to prepare better for the chemistry laboratories? _______________

8. Indicate the extent to which you agree to the following statements in relation to your experience within the labs.
Please tick your response to each item

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	I liked having to start the experiment myself without my tutors assistance					
b	I liked being able to finish the questions of the lab outside of lab time if I didn't get them finished					
c	The water problem 'Selgogg Abbey' allowed me to use skills I learned during 1st and 2nd semester					
d	The water problem 'Selgogg Abbey' made me link the chemistry I have done to 'real-life' applications					
e	The questions at the end of each experiment made me think about what was covered in the experiment					
f	The lab tutors were approachable and helpful					
g	Even though my tutor was grading me I was comfortable asking him/her questions					
h	The tutors questions made me think about the chemistry I was doing					
i	Answering tutor questions made me confident/clearer about the chemistry I was doing					
j	I did not like talking to my tutor since s/he was assessing me					
k	I received appropriate feedback from my tutor regarding my performance in laboratories					
l	I received appropriate feedback from my tutor regarding my understanding in laboratories					

PLEASE TURN OVER →→→

9. Indicate the extent to which you agree to the following statements in relation to your overall lab experience.
Please tick your response to each item

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	If I prepared properly for the lab there was enough time to complete the lab experiments					
b	I learned chemistry through the lab experiments					
c	I enjoyed/liked the chemistry labs					
d	I learned lab skills in the chemistry laboratories					
e	Overall I found the chemistry labs challenging but doable					
f	I found the theory of the chemistry in the labs difficult					
g	I found practical calculations difficult					
h	I found the laboratory manual easy to understand					
i	I found the practical part of the lab difficult					
j	I found writing a lab report easy					

10. **Please tick the appropriate boxes** indicating whether you agree or disagree to the statements in relation to the name experiments.

	I liked the experiment/activity		I learned from this experiment/activity		I didn't see the purpose of this experiment/activity	
	Agree	Disagree	Agree	Disagree	Agree	Disagree
1.1 Det. of water hardness using EDTA titration						
1.2 Analysis of Rubex by back titration						
1.3 Det. of dissociation constant of a weak acid						
1.4 Spec determination of an equilibrium constant						
1.5 Solid-liquid extraction of trimyristin from nutmeg						
EPA Water Problem 'Selgogg Abbey'						
Oral Presentation						
Practical Skills Assessment						
1.8 Dehydration of alcohol and isolation of it's products						
1.10 Synthesis of Aspirin						
1.11 Hydrolysis of trimyristin						
1.12 Qualitative determination of functional groups						

11. Which aspects of the 2nd semester laboratories would you advise to be changed for next years 1st years?

____

____

12. Indicate the extent to which you agree to the following statements : **Please circle your response**

		Very Strongly	Fairly Strongly	Somewhat /not sure	Rather Weakly	Very weakly
a	I am able to handle chemicals in the laboratory	5	4	3	2	1
b	I am able to handle glassware in the laboratory	5	4	3	2	1
c	I am aware of specific hazards relating to chemicals	5	4	3	2	1
d	I am able to measure and observe chemical events and changes	5	4	3	2	1
e	I am able to analyse and evaluate experimental data	5	4	3	2	1
f	I am able to interpret chemical information	5	4	3	2	1
g	I am able to select appropriate techniques and procedure	5	4	3	2	1
h	I can identify errors in chemistry experiments	5	4	3	2	1
i	I am able to maintain good laboratory notes	5	4	3	2	1

Phase 3: Laboratory Evaluation 2a (Time C)

This survey is being used for Postgraduate Research investigating students' 1st year experience of chemistry laboratories. **It is not for academic assessment.** All answers are **confidential**.

Please answer all questions in relation to your 2nd semester chemistry laboratories

Name: ____________________ Course: ________ Student No: ______________ Date: ______________

1. Indicate the extent to which you agree to the following statements in relation to the various assessments of 1st year labs. **Please circle your response in relation to the listed assessment methods**

	I feel the assessment method allowed me to demonstrate my 'abilities':	Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	Tutor questioning	5	4	3	2	1
b	Prelab	5	4	3	2	1
c	Lab notebook	5	4	3	2	1
d	Exam	5	4	3	2	1
e	Presentation	5	4	3	2	1
f	Lab Reports	5	4	3	2	1

	I liked the assessment method	Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	Tutor questioning	5	4	3	2	1
b	Prelab	5	4	3	2	1
c	Lab notebook	5	4	3	2	1
d	Exam	5	4	3	2	1
e	Presentation	5	4	3	2	1
f	Lab Reports	5	4	3	2	1

2. Indicate the extent to which you agree to the following statements in relation to a comparison between your interaction with 1st and 2nd semester labs. **Please circle your response to each item**

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	I became more motivated in 2nd semester labs	5	4	3	2	1
b	I tended to prepare more for the 2nd semester labs	5	4	3	2	1
c	I was better able to work on my own in the second semester	5	4	3	2	1
d	I felt more confident in the laboratory in the 2nd semester	5	4	3	2	1

3. Please note any differences between 1st semester and 2nd semester, either positive or negative:

Positive differences:

____

____

____

____

Negative differences:

____

____

____

____

Phase 3: Tutor Laboratory Survey 2 (Time C)

This survey is being used for Postgraduate Research investigating tutors' experience of chemistry laboratories. All answers are confidential. **Thank you for completing this survey.**

Please answer all questions in relation to your tutoring of chemistry laboratories

Name:______________________________________ Date:________________

1. Indicate the extent to which you agree to the following statements in relation to your opinion of the students' experience of the 1st year chemistry laboratories.

Please circle your response to each item

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	Students responded positively to questioning within the lab	5	4	3	2	1
b	Students put a lot of effort into the pre-labs	5	4	3	2	1
c	Students put effort into understanding the labs	5	4	3	2	1
d	Students general effort increased as the semester progressed	5	4	3	2	1
e	Students enjoyed the laboratory experience	5	4	3	2	1
f	Students were fairly rewarded for the work they put in	5	4	3	2	1
g	Your students did better than the average student	5	4	3	2	1
h	Students without leaving certificate chemistry struggled more than those who had done chemistry before	5	4	3	2	1
i	Students with leaving certificate chemistry put in less effort than those without leaving cert chemistry	5	4	3	2	1

2. Please use the space provided to make additional comments on the above questions if required: ____________

____
____
____

3. Indicate the extent to which you agree to the following statements in relation to your experience of the 1st year chemistry laboratories.

Please circle your response to each item

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	I built up a good relationship with my students	5	4	3	2	1
b	All my students demanded my time equally	5	4	3	2	1
c	It was possible to correct pre-labs during the lab session	5	4	3	2	1
d	It was possible to give student feedback on the pre-labs	5	4	3	2	1
e	It was possible to correct the notebooks within the lab	5	4	3	2	1
f	It was possible to give feedback on the notebooks within the laboratory	5	4	3	2	1
g	I was able to spend time with students who needed my time	5	4	3	2	1
h	I spread my time equally amongst all of my students	5	4	3	2	1
i	I found it easy to ask students challenging questions	5	4	3	2	1
j	I prepared for each lab session before entering the lab	5	4	3	2	1

4. Please use the space provided to make additional comments on the above questions if required: ____________

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PLEASE TURN OVER → → →

5. Did you enjoy the tutoring experience? Yes ☐ No ☐

Please comment on your answer: ____

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6. **Please circle the appropriate boxes** indicating whether you agree or disagree to the statements in relation to the name experiments.

	Suitable level for the students		Aims were clear		Manual was clear		Questions in manual were clear	
	Agree	Disagree	Agree	Disagree	Agree	Disagree	Agree	Disagree
1.1 Det. of water hardness using EDTA titration	x	x	x	x	x	x	x	x
1.2 Analysis of Rubex by back titration	x	x	x	x	x	x	x	x
1.3 Det. of dissociation constant of a weak acid	x	x	x	x	x	x	x	x
1.4 Spec determination of an equilibrium constant	x	x	x	x	x	x	x	x
1.5 Solid-liquid extraction of trimyristin from nutmeg	x	x	x	x	x	x	x	x
EPA Water Problem 'Selgogg Abbey'	x	x	x	x	x	x	x	x
Oral Presentation	x	x	x	x	x	x	x	x
Practical Skills Assessment	x	x	x	x	x	x	x	x
1.8 Dehydration of alcohol and isolation of it's products	x	x	x	x	x	x	x	x
1.10 Synthesis of Aspirin	x	x	x	x	x	x	x	x
1.11 Hydrolysis of trimyristin	x	x	x	x	x	x	x	x
1.12 Qualitative determination of functional groups	x	x	x	x	x	x	x	x

7. Indicate the extent to which you agree to the following statements in terms of your preparedness for tutoring within the chemistry laboratory: **Please circle your response to each item**

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	I felt prepared in relation to the chemistry being covered in the laboratory sessions	5	4	3	2	1
b	I felt I was prepared in relation to the practical activity that was being coved in the laboratory	5	4	3	2	1
c	I knew what was expected of me within the labs	5	4	3	2	1
d	I felt I was prepared to interacting with students	5	4	3	2	1
e	I understood how I was going to assess the students pre-labs	5	4	3	2	1
f	I understood how I was going to assess the students understanding of the experiment	5	4	3	2	1
g	I understood how I was going to assess the students notebook	5	4	3	2	1
h	If I was unsure about any aspect I was able to ask someone for advice/help	5	4	3	2	1
i	The handouts of the experiments were useful	5	4	3	2	1

9. Indicate the extent to which you agree to the following statements in relation to your students interaction in labs in 2nd semester labs. **Please circle your response to each item**

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	My students motivation increased as the semester progressed	5	4	3	2	1
b	My students preparation increased as the semester progressed	5	4	3	2	1
c	My students became more independent carrying out experiments as the semester progressed	5	4	3	2	1
d	My students were more confident as the semester progressed	5	4	3	2	1

10. Please use the space provided to make additional comments on the above questions if required: ___________

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11. **Only complete this question if you were a tutor for both first and second semester:**

Indicate the extent to which you agree to the following statements in relation to a comparison between your students interaction with 1st and 2nd semester labs. **Please circle your response to each item**

		Very strongly	Fairly strongly	Somewhat /not sure	Rather weakly	Very weakly
a	My students were more motivated in semester two	5	4	3	2	1
b	My students prepared better for 2nd semester labs	5	4	3	2	1
c	My students were more independent carrying out experiments in the 2nd semester	5	4	3	2	1
d	My students were more confident in the 2nd semester	5	4	3	2	1

12. Please use the space provided to make additional comments on the above questions if required: ___________

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All tutors:

13. Please add any additional comments and advice for next years 1st year implementation:

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Thank you ☺