UNIVERSITY of LIMERICK

OLLSCOIL LUIMNIGH

'The Use of an Intervention Programme to Improve Undergraduate Students' Chemical Knowledge and address their Misconceptions'

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Declaration

I hereby certify that this material which I now submit is entirely my own work and has not been taken from the work of others. Any work referred to has been cited and acknowledged within the text of my work.

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Date:_______________________

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Abstract

The increase in the percentage of Irish students entering third level education means that many students choosing Science programmes do not have an adequate foundation in Science. This study is an attempt to increase retention amongst under-prepared students in undergraduate Science programmes by providing support to improve their Chemistry understanding.

An Intervention Programme was designed for three course groups of students, who have been previously identified as low-achievers in Chemistry. This programme consisted of two semesters of tutorials: Phase 1 focusing on basic Chemistry concepts and ideas and Phase 2 focusing on the mole and chemical calculations. The tutorials utilised various strategies including peer-learning and assessment, formative assessment and inquiry-based learning. A pre- and post-diagnostic test of chemical concepts and misconceptions was designed and administered in the first and last tutorial session of each phase. Students' performance in both the pre- and post-diagnostic tests was measured, but this could only be done for students who had completed both the pre- and post-test. The tests also included a published instrument for measuring student attitudes and confidence towards Chemistry.

The pre-diagnostic tests were used to design the content of the Intervention Programme to meet students' specific needs. The students were taken in small class groups, rather than large lecture groups. The Intervention Programme ran over two semesters, starting in the second semester of first year. It involved a blended learning approach, which entailed a combination of face-to-face teaching and learning, as well as online resources. By using a variety of pedagogical techniques, it was expected that students from these groups were better equipped with the basic chemical understanding that they needed for their undergraduate programmes of study, resulting in greater retention.

Results of the Intervention Programme have shown a positive trend in both conceptual understanding and confidence levels in Chemistry. In all phases, students did significantly better in the post-diagnostic test than in the pre-diagnostic test. Throughout the three phases, a large number of students

completed a pre-diagnostic test and did not return to complete a post-diagnostic test. Results from these pre-diagnostic tests have shown that students are showing similar misconceptions whether they have studied Chemistry for their Leaving Certificate Examinations or not. It also provides evidence that many students entering third level education are under-prepared for the demands at third level. Where possible, the performance of students who participated in the Intervention Programme in their concurrent Chemistry module examination was compared with the performance of students who did not participate in it in their concurrent Chemistry module, and this showed that students who had participated in the programme did better in their examination than those who did not participate, which was significant in most cases. This improvement will be beneficial in relation to student retention. Semi-structured interviews were also carried out with six students who had participated in the Intervention Programme. However, while the results are encouraging, poor and inconsistent attendance in both the main module and in the Intervention Programme has affected the results.

The programme has also highlighted the importance and value of diagnostic testing to target students' difficulties in Chemistry and helping low-achieving students to improve their performance in their courses of study. This study has shown that many students are under-prepared to study Chemistry at third level, and hold many chemical misconceptions. Failure to address this problem early on through an Intervention Programme, like the one described here, will to continue to result in high failure rates and low levels of student retention.

Chapter One

Introduction

1.1 Introduction

This chapter gives an overview of the aim and purpose of this study as well as an insight into the position of Chemistry in the Irish Education System.

1.2 Aim of Investigation

This study aims to review the literature on student retention and poor performance in Science programmes at University level and to design, develop and evaluate a targeted Intervention Programme. This was designed for the first and second years of three groups of Chemistry students (Environmental Science students, Health and Safety students and Food Science and Health students) in the University of Limerick. These three groups of students have previously been identified as low-achievers by their Chemistry lecturers based on previous module results. The aim of the Intervention Programme is to improve students' understanding of the fundamental ideas and concepts of Chemistry and thus improve students' success rates in their chosen courses of study. This was achieved by using the findings of Chemistry Education Research, particularly in the area of chemical misconceptions, to design a diagnostic test to uncover the specific problems and misconceptions held by students. The project aims to investigate whether taking a 'smarter' approach to teaching (Perkins, 2007) can improve student performance and increase retention rates.

1.3 Background of Investigation

The education system in Ireland is rapidly changing. Like many other countries, Ireland is experiencing a surge in the number of students taking up third level education. The Irish government's expansion policy on education has resulted in much higher numbers pursuing higher education than ever before- currently 65% of the age cohort (Department of Education and Skills, 2011). In addition, the current economic climate has led to a large number of mature students returning to higher education to retrain and improve their job prospects as well as an increase in the numbers of students choosing to undertake a postgraduate programme in third level education rather than go into the workplace. In addition, there is a wider range of abilities and diversity in educational background entering higher education than in the past. There is also an increase in the number of non-standard students as well as non-national students joining them, with few of these students having completed Leaving Certificate Chemistry or an equivalent course.

Many students who are choosing to study Science-related courses at third level do not have an adequate foundation in Science or Mathematics (Walshe, 2007). They do not need to have completed Chemistry at school to study it at University. They find it difficult to pick up Chemistry at University and often do badly and in the worst case, drop-out of study. The main reasons for these students having such difficulty are they have studied little or no Chemistry at second level and their overall academic background is weak, as measured by their Leaving Certificate results and Central Applications Office (CAO) points. Many mature students, or as they will be referred to in this study, non-standard students, have a problem with Mathematics as they have not studied it for some years and for many, English may not be their first language which makes their situation more difficult. As a result, this makes it more difficult for students to cope with and succeed in their studies. In 2010, just under 14% chose to study Chemistry for their Leaving Certificate Examination (Childs, 2011; DES, 2010). Many of the students do not have an adequate grounding in the basics of Chemistry for studying it in higher education, where Chemistry is often a required course in first year. Entry requirements into Science courses in Ireland usually only require students to have studied one of the following Science subjects: Agricultural Science, Biology, Chemistry, Physics and Physics & Chemistry, at either higher or ordinary level. In the early modules studied in these Science courses, students without an adequate background in Chemistry are often left behind (Childs and Sheehan, 2009; Hayes and Childs, 2010).

The specific problem found in Ireland, where greater numbers of unprepared students entering higher education, is mirrored in the UK (The Royal Society, 2011). This problem, unsurprisingly, leads to high drop-out rates (Moore, 2004) and high failure rates in many Universities, particularly in Science and Technology courses. It is of vital importance that these students are not lost or left behind. In order to accommodate this diverse group, more varied and student-friendly teaching and learning supports need to be put in place.

Cottrell (2001) describes that Universities need to change in order to accommodate the new student intake. Unless these students are supported and given the time and help they need, they are at risk of non-completion of their third level studies. It has been noted that more '*fine-grained*' approaches are needed to tackle '*student under-performance, student persistence, retention and academic success'* (Moore, 2004). Allowing students to enter University and not giving them the help they need to succeed, is a waste of resources at all levels – personal, institutional and societal.
This research project was carried out in the University of Limerick and looks at the teaching and learning of Chemistry in the Irish Education System. In total there were 106 students were involved in the project but only 63 of these students participated fully (attended 6 or more tutorials and completed a post-diagnostic test).

1.4 Research Questions

The research questions that have guided this study are:

1 How well prepared are students to study Chemistry at third level and do they share common misconceptions?

2 Can diagnostic tests, that identify students' prior chemical knowledge and misconceptions, be used to design an effective Intervention Programme?

3 What effect does prior Mathematics background have on student performance on pre- and post-diagnostic tests?

4 Can a targeted Intervention Programme improve students' performance in the post-disgnostic test compared to their performance in the pre-diagnostic test?

5 How does attendance at the Intervention Programme make a difference in the students' overall performance in their concurrent Chemistry modules?

6 Can students' attitude and confidence towards Chemistry be improved

by taking part in a targeted Intervention Programme?

1.5 Structure of the Thesis

Chapter 1 ~ Introduction

This chapter provides a brief account of the background of this project as well as the aim and research questions of the project. It explores issues such as the increase in the number of students in third level education, the diversity in student backgrounds and the increase of non-standard students and non-national students in higher education. The combination of these issues can lead to various problems and difficulties which will be discussed in later chapters.

Chapter 2 ~ Literature Review

This chapter will discuss in detail the place of Chemistry in the Irish education system as well as its place in third level education. The reasons why Chemistry is seen as a difficult subject for students will be examined. The assessment and teaching methodologies used in this Intervention Programme will also be reviewed.

Chapter 3 ~ Methodology

This chapter describes how all phases of the Intervention Programme were carried out. It will describe the design of the testing instrument used, the design of the tutorials and the resources used, group profiles that participated in the programme and why certain approaches were used. The analysis of the pre- and post-diagnostic tests will also be outlined in this chapter.

Chapter 4 ~ Results

This chapter provides graphical representations of the main findings and results of this study, as well as the results of the student interviews which were conducted.

Chapter 5 ~ Discussion

This Chapter gives a detailed description of the main findings and discusses the significance and the implications of these findings.

Chapter 6 ~ Conclusion

This chapter will draw together the final conclusions from the project as well as answering the research questions that were outlined in Chapter 1.

Chapter Two

Literature Review

2.1 Introduction

This chapter gives an account of the Irish Education System, difficulties in Chemistry and also existing research on the teaching and learning of the subject. It also discusses the background to some approaches to teaching and learning used in the tutorials that took place during the Intervention Programme.

2.2 The Irish Education System

The Irish Education System is divided into Primary Level Education which lasts 8 years and Second Level Education which lasts five or six years, depending on whether pupils decide to participate in an optional 'Transition Year'. After this, pupils then decide if they want to progress onto Third Level Education. Figure 2.1 shows the overall structure of the Irish Education System. Each level of the system will be outlined in the following sections.

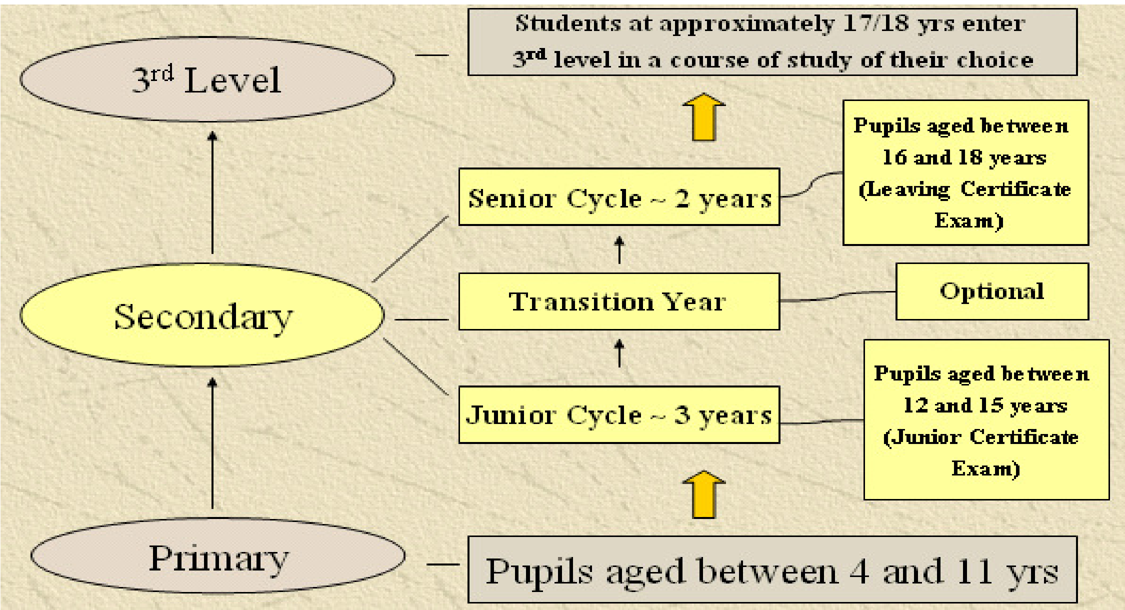


Figure 2.1 The Structure of the Irish Education System.

2.2.1 Primary Level Education

Most pupils begin their formal education aged approximately four or five years in the primary cycle. Primary pupils have had compulsory Science within the primary curriculum since 2003. It consists of a broad Science syllabus called Social, Environmental and Scientific Education. The curriculum is made of four strands: Living Things, Energy and Forces, Materials and Environmental

Awareness and Care. Pupils finish their primary schooling aged approximately eleven or twelve years.

2.2.2 Second Level Education

Following Primary Education, pupils begin the first three years of their second level education. This is known as the Junior Cycle, and Science is not compulsory at this stage of the pupils' education. Ireland is one of the few countries in Europe not to have compulsory Science at any stage of second level schooling. This means that the pupils' experience of Science is dependent on the type of school that they attend, with the lowest levels of provision of Junior Science being in single sex female schools. (Smyth and Hannon, 2002). The Junior Cycle culminates in the first state examination, the Junior Certificate, where pupils study 8-12 subjects. All students must take Irish (except where exemptions apply), English, Mathematics and Civic, Social and Political Education. There may be other compulsory subjects, depending on the type of school. Once pupils have finished the Junior Cycle they have the option to take the Transition Year. This is an optional extra year in second level which is curriculum-free and aims to offer an opportunity for personal growth, development and maturity. Just over three quarters of schools offer the Transition Year, and just over half the pupils take it. If pupils decide to take this year they can then progress on into the Senior Cycle afterwards. If students do not take the Transition Year they will proceed straight into the Senior Cycle.

The Senior Cycle lasts two years and concludes with another state examination, the Leaving Certificate. The results of this examination will determine whether pupils can enter a third level institution to pursue a course of their choosing. In the Leaving Certificate, a minimum of six subjects must be studied, with most students taking 7 subjects. The only compulsory subject that students must take for the Leaving Certificate is Irish, however, the vast majority of schools have made it compulsory to take English and Mathematics also, as entry into a third level institution without these subjects is almost impossible. As Childs (2006) noted, this is one of the strengths of the Irish Education System, with over 90% of candidates taking Mathematics for their

Leaving Certificate. School leaving age is sixteen and this marks the end of compulsory schooling.

Science is not compulsory, although most pupils take at least one Science subject for their Leaving Certificate Examination. Pupils have the choice of studying one or a combination of five Science subjects namely Agricultural Science, Biology, Chemistry, Physics and Physics with Chemistry (combined course). There is poor uptake of the Physical Sciences at Senior Cycle, with a typical uptakes ranging from 12-14% for Physics and Chemistry. Biology is a more popular choice, with over 50% of the cohort taking this subject at Leaving Certificate level. See Figure 2.2. Agricultural Science has grown in popularity and is now just behind Physics in terms of the uptake rate.

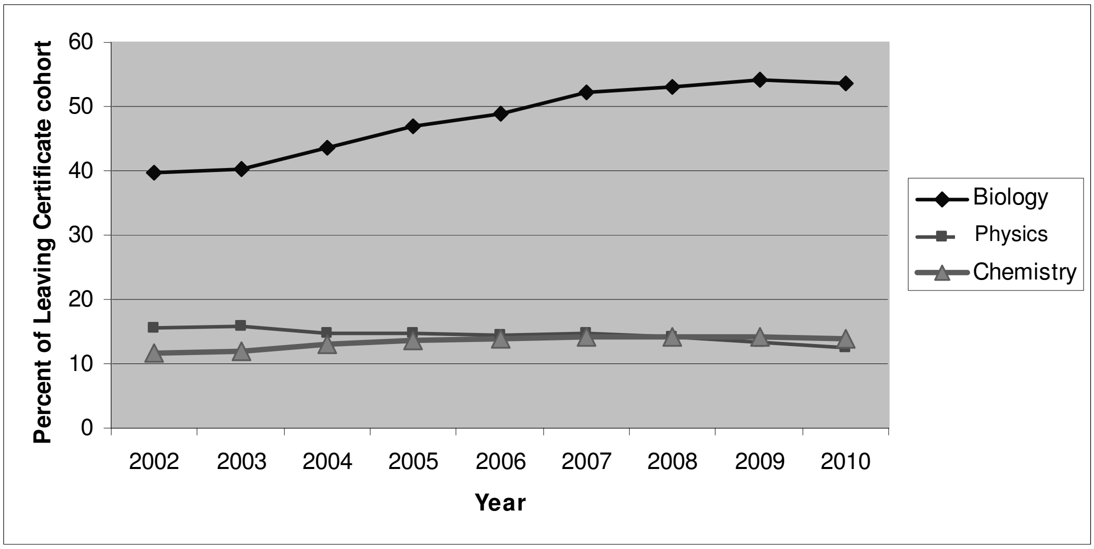


Figure 2.2. Percentage of Leaving Certificate Pupils studying Biology, Chemistry and Physics.

All subjects offered in Senior Cycle can be taken at two levels: higher level and ordinary level. There is a third option for pupils who are particularly weak in Mathematics and Irish, and this is the foundation level. Although, taking Mathematics at foundation level excludes pupils from most forms of third level education. Higher level Mathematics is typically taken by ~16% of the cohort for Senior Cycle.

Each pupil receives points in each subject after they have completed their Leaving Certificate examinations. These points are then used to get into a third level course. A pupil’s six best examination subjects are used to calculate their final points score. An A1 grade in a higher level paper can earn a pupil 100 points and a D3 grade earns 45 points. A maximum of 600 points can be achieved through the 6 subjects, although from 2012 all Universities are offering 25 bonus points for higher level Mathematics (Donnelly, 2010).

2.2.3 Third Level Education

The last ten years has seen the largest increase in numbers at third level, with over 65% of 17-18 year olds now entering third level education, and the stated government goal is to reach 72% by 2020 (Higher Education Authority, 2006).

Ireland has a two-tier or binary third level system with Science courses being offered in both Universities and Institutes of Technology. Ireland has a National Qualifications Framework (NQF) ranging from level 1 (primary) to level 10 (doctorate). Science courses are offered at Universities as level 8 courses (honours degree) and at Institutes of Technology, as level 6 (certificate), level 7 (ordinary degree) and level 8 courses (honours degree). This means that there is a considerable overlap between the two sectors. However, traditionally Universities would have a higher status and offer most of the level 8-10 courses. A further separation of these two sectors has been discussed, as currently there are no strategic objectives distinguishing the two systems (Royal Irish Academy, 2009).

University honours degree courses in Science start from as low as 300 points, with the equivalent courses starting from 205 points in Institutes of Technology. However, most Science courses at Universities start from 350 points upwards, depending on the particular course and the institution. Courses with a higher demand, such as medicine, pharmacy and law, can start from over 500 points, with most needing over 550 points for entry. Science courses are less popular and attract weaker students on average than these professional courses. Course entrance points are determined each year through a supply and demand system administered by the Central Applications Office (CAO). Essentially the points required are based upon the number of student places and the demand for these places. Therefore the number of points that one needs to be accepted into a third level degree programme does not necessarily reflect the difficulty of the course, rather its popularity in relation to the number of places available. Points for entry into courses in third level institutions change from year to year depending on demand, so that in 2010 and 2011, for example, points rose for most courses due to higher demand. The last two years saw an increase in the number of students applying for Science courses, an increase of 14% in 2010 and an increase of 6% in 2011. The Leaving Certificate examination results, third level applications and offers of course places from the third level institutions are all processed through the CAO.

The subjects Irish, English and Mathematics taken at Leaving Certificate level are entry requirements for Irish applicants for many courses but the remaining subjects are the student's choice. Entry requirements into Science courses usually only require students to have studied one of the following Science subjects: Agricultural Science, Biology, Chemistry, Physics and Physics & Chemistry, at either higher or ordinary level.

2.2.3.1 Expansion and Diversity in Third Level Education

Third level education in Ireland is rapidly changing. Like many other countries, Ireland is experiencing a surge in the number of students taking up higher education. The Irish government's expansion policy on education has resulted in much higher numbers pursuing higher education than ever before; currently 65% of the age cohort (Department of Education and Skills, 2011). It is estimated that between 2009 and 2018 the total number of full time students enrolled in higher education will increase by almost one third, going from 155,000 to almost 204,000 (Forfás, 2009).

There are many reasons for this expansion. In the current economic climate, more pupils are deciding to progress into third level and further their education to improve their job prospects. This expansion has led to the enrolment of a cohort of school-leavers whose levels of preparation and attainment are less than those of students who entered Universities and Institutes of Technology in the early 1990s.

As well as this, there is a large number of non-standard students returning to third level education to retrain in different areas in the hope of securing a job. While the large numbers entering third level education are seen as progressive and an improvement in the education system, it does lead to the problem of a very diverse group of students in higher education, both in ability and educational background (Childs and Sheehan, 2009; Darmody and

Fleming, 2009). The increase in numbers entering third level has also resulted in an increase in students entering Science courses. Table 2.1 shows the number of students entering designated Science courses at third level.

Table 2.1 Number of students entering designated courses of study 2009/10 based on (Higher Education Authority, 2010)

Full Time Undergraduates entering 3rd level 2009/10			
Field of Study	***University Level***	***Institute of Technology Level***	***Total***
Chemistry	105	117	222
Physics	192	55	247
Mathematics	98	18	116
Medicine	633	35	668
Pharmacy	127	153	280
Veterinary	155	72	227
Law	818	177	995

2.3 Chemistry at Third Level

Science courses at third level in Ireland are facing a particular problem. These courses, like others of their kind across Europe, experience a high level of attrition among students. Science and Mathematics courses across Europe have lower completion rates than other courses, such as Arts and Law. This is also true for Irish courses, with these courses having significantly higher rates of attrition (14%) in comparison to courses such as Law (3%) (Higher Education Authority, 2010). A number of factors are involved in these low levels of completion. Firstly, as mentioned previously there are low numbers of students taking the Physical Sciences and higher level Mathematics at second level education. This leads to many students who are ill-equipped and under-prepared to take a Science course at third level. This is partly due to the fact that students who enter third level Science courses are not always required to have taken a relevant Science subject for their Leaving Certificate. Seery (2009) noted that "*Chemistry is taken by 10-15% of students in the senior cycle of school (Leaving Certificate) in Ireland, and therefore tertiary institutions cannot impose a prerequisite of Chemistry for entry into Chemistry based degrees because of the limited pool of potential applicants*". However, the students who have not taken Chemistry at school do not have an adequate grounding in the basics of the subject for study at third level, where

Chemistry is often a required module in first year. In the early modules studied in these Science courses, these students without an adequate Science background are often left behind. (Childs and Sheehan, 2009; Hayes and Childs, 2010).

Secondly, students with a wider range of educational backgrounds are entering higher education than in the past. Since students who enter the third level Science courses are not required to have taken the relevant Science subject at Leaving Certificate, this has become a crucial issue in undergraduate Chemistry classes at third level. A discussion document produced by the Royal Irish Academy (2009) argued that "*a student should only be accepted for a course from which there was a reasonable expectation that he or she would graduate.*" The CAO system offers students courses at both level 7 and level 8, which they can apply for separately. Most students opt for the higher level course, often at a University, even if they are insufficiently prepared. Currently, Universities, and particularly Institutes of Technology, are accepting some students who have achieved below the 50^{th} percentile in their CAO points score. The low levels of points required for undergraduate Science courses attracts students who are insufficiently prepared, but may also deter many high achieving students, as they believe it to be a low status option. Many incoming students are inadequately qualified, which is a reflection of the allocation of government funding which is based on student numbers with little regard for educational performance. There is also the risk of "dumbing down" of academic courses (Walshe, 2007). This means that institutions are tempted to lower standards to avoid massive failures and to hold on to their academically weaker students. Students who are under-prepared for third level in Mathematics and Science are still meeting the minimum requirement for various courses but this does not necessarily mean that they will be able to cope with the demands of their chosen course.

Thirdly, in addition, access programmes for non-traditional students have increased the number of under-prepared students. Access programmes are in place to ensure that third level places are given to a number of students from disadvantaged backgrounds, who may get below the standard course requirements in their Leaving Certificate or may even not have completed the

Leaving Certificate Examination. In addition, more unemployed people are returning to education due to the economic situation.

It is clear that a number of weaker students in University undergraduate Science courses would benefit from the smaller class sizes, practical-based courses and more individual attention received by students in undergraduate Science courses in Institutes of Technology. Students when offered a choice of a degree course (level 8) at University or an ordinary degree course (level 7) at an Institute of Technology, will choose the higher status course. Unfortunately as Talanquer and Pollard (2010) note "*the first year Chemistry curriculum at most Universities is still mostly fact based and encyclopedic*", and this is true of many Irish Universities. However, in order to provide an appropriate learning environment for all students, the vast body of research on the teaching and learning of Chemistry also needs to be taken into account, in order to deal with this diverse group of students and help them to make up their deficiencies and increase their chances of completion.

2.4 Chemical Education Research

There has been a vast amount of research conducted in the area of teaching and learning of Chemistry over the past 40 years, which suggests that there are a number of areas to be addressed (Bodner, 1991; Gabel, 1999; Monk and Osborne, 2000; Reid 2008; Johnstone, 2010, 2006, 1997). Many have argued that we introduce concepts that are too abstract for students to deal with at their stage of cognitive development (Nakhleh, 1992; Canpolat *et al.*, 2006). Chemistry is a conceptually difficult and complex subject. As a result, students may find the various abstract concepts and ideas that they are being asked to hold within their working memory far too complicated, as they are not expert enough to 'chunk' the information. Despite this research we still often present chemistry concepts as ideas which are clustered in indigestible bundles (Johnstone, 2010; Sheehan, 2010; Chiu, 2005). Studies have shown that many students are not reaching formal operational thinking as early as Piaget had originally thought, and this makes Chemistry an almost intractable subject for many pupils (Shayer and Adey, 1981; Shayer *et al.,* 2007; Sheehan, 2010). Many students have numerous chemical misconceptions and it is widely accepted that if chemical misconceptions are not addressed at second level, preferably early on, they will persist (Nakhleh, 1992; Schmidt, 1995; Coll and Taylor, 2001). These misconceptions are typically deep rooted and difficult to change, and they must be specifically addressed. Childs (2009) has pointed out that to improve chemical education we need to integrate what is learnt from chemical research into the teaching and learning of Chemistry. We need to use theory to improve and inform practice. Recent work by Childs and Sheehan (2009) in Ireland has shown that the difficulties in Chemistry and student misconceptions persist into third level, because they have never been adequately addressed. Some of the issues raised by chemical education research that need to be addressed in teaching Chemistry at second and third level are:

- Chemical misconceptions held by students
- Cognitive level of students
- Memory overload
- Poor transfer of Mathematical skills
- Poor prior knowledge
- Overloaded curricula
- Poor visualisation skills
- Language problems

2.4.1 What makes Chemistry difficult?

Chemistry is a difficult subject for learners and this is partly due to the abstract nature of the subject. There are a number of factors that contribute to the complexity of Chemistry (see Figure 2.3), which make understanding and learning difficult for students.

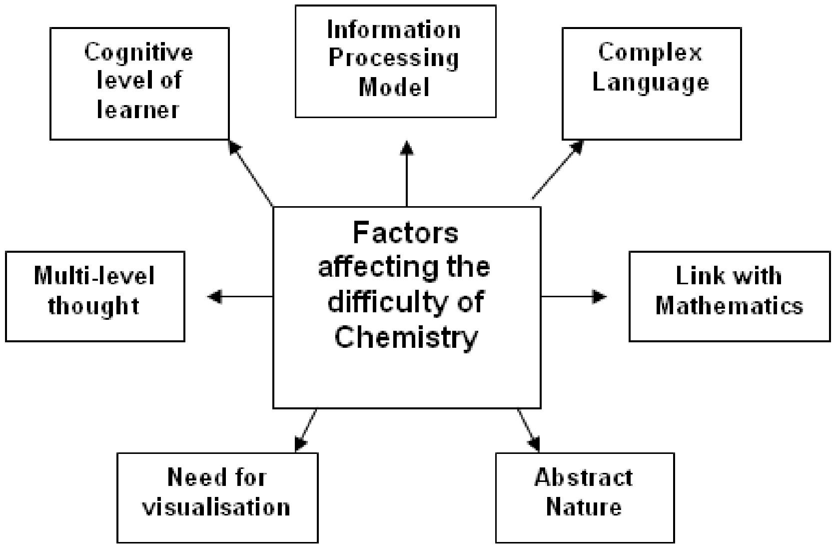


Figure 2.3 Contributing factors to the difficulty of Chemistry (Author).

2.4.1.1 Prior Knowledge of Students and Misconceptions

Learning is a process meaning that new information presented to the learner is firstly compared with prior knowledge and if an appropriate association can be made, the new information is fed back into the same knowledge base. How learners develop their own understanding of new ideas is dependent on their previous understanding of a related topic. The constructivism approach is beneficial to the student as it results in more meaningful learning allowing the student to build new knowledge on the foundations they already have. Constructivism is important as it leads to active and motivated students who are autonomous learners (Gray, 1997). Concepts are essentially a set of propositions that the learner uses to infer meaning for a particular topic. It is important to be aware that learners construct these concepts using information from two sources: what is formally taught to them from the teacher and also their informal prior knowledge from everyday experiences. The learner can connect new information to previously developed knowledge. This This means that even though teachers try to teach concepts and new ideas, the learner will in fact build their own concepts, which are often somewhat different from what was intended. When false concepts are developed by the pupils, new information cannot be connected correctly. This leads to the development of misconceptions or alternative concepts (Taber, 2010).

It is essential that these misconceptions and students' prior knowledge is accounted for. Research indicates that the role of prior knowledge is the most significant and important factor in determining students' future performance in year 1 of study (Seery, 2009), although it is important to note that there is no statistically significant relationship between exam marks in year 2 onwards and having prior knowledge of Chemistry (Seery and Donnelly, 2011). Keeping this in mind, it is imperative to assess the learners' prior ideas and then plan the teaching and learning experience around this prior experience (Taber, 2000). In this way students are given the opportunity to build upon the knowledge they already have and to correct any misunderstandings early on. Misconceptions in Chemistry are widespread among students. The literature reports on a wide range of areas where students commonly misunderstand the Chemistry content that they are taught. Misconceptions can act as 'barriers' for meaningful learning and must therefore be addressed (Taber, 2000). Childs and Sheehan (2009) also report on areas of difficulty in Chemistry in Ireland and how they can persist throughout education, from second level to third level. Their study indicates that '*performance at higher levels is being significantly affected by a failure to master core ideas earlier in their Chemistry education*'. This poor understanding of a topic is often due to rote learning. As no connection can be made with any previous knowledge, this leads to information being difficult to retrieve and it can easily be lost. Inaccurate recording of material in lessons and lectures can also lead to students learning incorrect facts and concepts. It is clear that action is needed to try to ameliorate these difficulties that students experience in their third level studies.

The standard approach of presenting new topics and ideas through lectures is still common practice in most Universities. This traditional, passive method of teaching and learning forces students to learn off material without fully understanding the content and does not build on what they already know. As a result, '*student perception of how to learn Science, in particular Chemistry, is to memorise material covered in the classroom*' (Lamba, 2009). This type of learning leads to surface learning and short-term recall. Cottrell (2000) agrees that students who adopt a rote learning approach do '*not develop a range of skills appropriate to higher education'*. In order to shift this type of learning to more meaningful understanding, deep learning must be promoted as much as possible. A deep learning approach refers to active engagement with a task in order to obtain deep meaning (Lovatt *et al.,* 2007).

2.4.1.2 The Multi-dimensional Nature of Chemistry

Chemistry is seen as a challenging and difficult subject by many third level students especially if the student has no prior experience of the subject. The abstract concepts of Chemistry require multi-level thought. This multi-level thought was represented by Johnstone (1991) as the 'Triangle of Chemistry' (Figure 2.4). His planar triangular representation of Chemistry showed three levels of thought that are presented to the learner. These three levels are the Macroscopic, Sub-microscopic and Symbolic. The 'Macro' level refers to what is visible e.g. a solid being dissolved in a liquid. The 'Sub-microscopic' level refers to what is molecular and invisible e.g. ions and atoms, and the third level is 'Symbolic' or 'Representational'. This refers to the chemical symbols, formulae and equations that represent the ions, atoms and molecules. Students, however, sometimes find it difficult to transfer from one conceptual level to another. It is important to be able to move from the macroscopic to the microscopic, from the concrete to the abstract, for example by using physical models to describe molecular structures. The use of such models and also real examples allows the learner to visualise areas of Chemistry, which can sometimes be abstract concepts that students find difficult to comprehend (Childs, 2009).

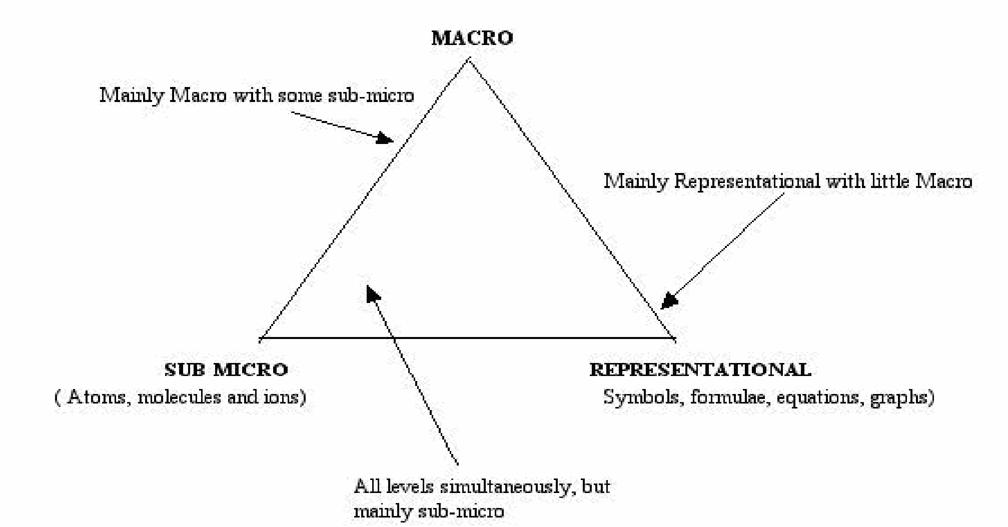


Figure 2.4 Three levels of Chemistry.

While someone who is competent in Chemistry may be able to easily move between these levels of thought without difficulty, the combination of just any two of these levels can be demanding on a student who has limited or no prior knowledge and understanding of Chemistry. Johnstone (2000b) described it as '*psychological folly'* to introduce learners to all three levels of thought simultaneously, but this is what teachers and lecturers often do.

Johnstone (2006) recommended beginning at one corner of the triangle, and then moving along one side towards another corner before moving towards the centre of the triangle. This approach to teaching can facilitate the learners' level of understanding of each aspect of Chemistry, rather than if all aspects are introduced at once. The expert has learned to use all three levels and move between them easily, but is often unaware of the difficulties they present to beginners in the subject. The ability to understand these three levels also related to the students' cognitive level, as discussed below in section 2.4.2.1.

2.4.1.3 The Language of Chemistry

> *'A major challenge to students learning Science is the academic language in which Science is written. Academic language is designed to be concise, precise, and authoritative. To achieve these goals, it uses sophisticated words and complex grammatical constructions that can disrupt reading comprehension and block learning. Students need help in learning academic vocabulary and how to process academic language if they are to become independent learners of Science.'* (Snow, 2010)

Another contributing factor to the difficulty of Chemistry is the complex language used in the subject. As well as the introduction of new vocabulary to the learner, the use of words which students have already developed an understanding of outside of Science often creates further confusion (Nakhleh, 1992). It is difficult for the learner to develop a clear, conceptual understanding of the scientific meaning of words which they have previously learned outside of Science e.g. energy. This can therefore act as a barrier to students' learning. Chemistry and chemical symbols are inextricably linked, and therefore the learning of Chemistry depends largely on a learner's ability to use the required symbolic language with some degree of comfort. Johnstone (2010) recognised how complex language can lead to problems in the Long Term Memory when a word which was familiar then changes meaning. Childs (2006) highlighted literacy and numeracy as two '*essential pre-requisites*' for Science Education. Chemistry requires the learner to learn a new language. Correct chemical grammar and punctuation needs to be learned to balance and interpret chemical equations. Numeracy is also developed in the Mathematics classroom and then applied in the Science laboratory. Science and Mathematics are often taught in mixed ability classes. This complication makes it more challenging for the teacher to accommodate the learners at the higher and lower ends of this spectrum. As well as this, there is the added difficulty of words which have other meanings outside of Science which are used in everyday language such as 'strong' and neutral (Jasien, 2010;2011). Adding to this complication for the teacher is the increasing number of pupils in Irish classrooms whose first language is not

English (Childs and O' Farrell, 2003). This then creates another problem with communication.

2.4.1.4 Mathematics

Science and Mathematics are very closely linked and dependent on each other. One benefit of the Irish Education System is that the majority of pupils continue to learn Mathematics until the end of their second level education. Childs & Sheehan (2009) have identified the Mathematics ability of the learners at second and third level education in Ireland as a contributing factor to difficulties experienced in Chemistry. As well as sharing symbols, numbers and equations, Science and Mathematics also both use visualisation to represent data. A good understanding of either subject facilitates the learner's ability to interpret graphs and diagrams. However, while both subjects are inter-linked, disconnected curricula do not allow the integration of both subjects (Engineers, 2010). An area of cognitive confusion for the learners is when teachers of different subjects present the same material but in different ways, using different terminology or symbols, or avoid teaching the same material, assuming that the teacher of the other subject has done so.

2.4.2 Understanding Chemistry

For many learners, it is difficult to recognise the value of developing scientific knowledge. Learning and understanding Science can often be a daunting task, as it involves the establishment of new concepts as well as the reconstruction of prior knowledge. This is particularly difficult due to the abstract nature of the subject which requires the learner to accept agreed knowledge and facts, while also encouraging an inquiry-based approach to the subject. Many models of learning need to be considered when addressing the difficulties of learning Chemistry. These include the stages of development outlined by Piaget (Libby, 1995), Ausubel's inadequacy of previous knowledge and limited working space related to age (Johnstone and El-Banna, 1989), as well as the Information Processing Model (Johnstone, 1997). In a study carried out by Childs & Sheehan (2010) amongst second level pupils and third level students in Ireland, the cognitive development of the pupil and thus their information processing ability were identified as a factor in finding Chemistry difficult. The other two main findings of the same study highlighted the mathematical ability of the pupil and the pupils' misconceptions as contributing factors in their perception of the difficulty of Chemistry.

2.4.2.1 How students learn

Linking new information to the learners' previous experience and knowledge involves approaching a new topic from an angle where the learner can see some association with an established framework in their Long Term Memory. According to the Information Processing Model (Johnstone, 1997), the learner's mind will only assimilate new concepts which can in some manner be linked to previous conceptual frameworks.

Piaget (1964) outlined a sequence of operational stages of cognitive development of children. Details of each stage of cognitive development are included in Figure 2.5. Piaget (1964) predicted that progression between these stages of cognitive development was dependent on the age of the learner. These age categories are illustrated in Figure 2.5 below, in relation to their corresponding levels of cognitive ability.

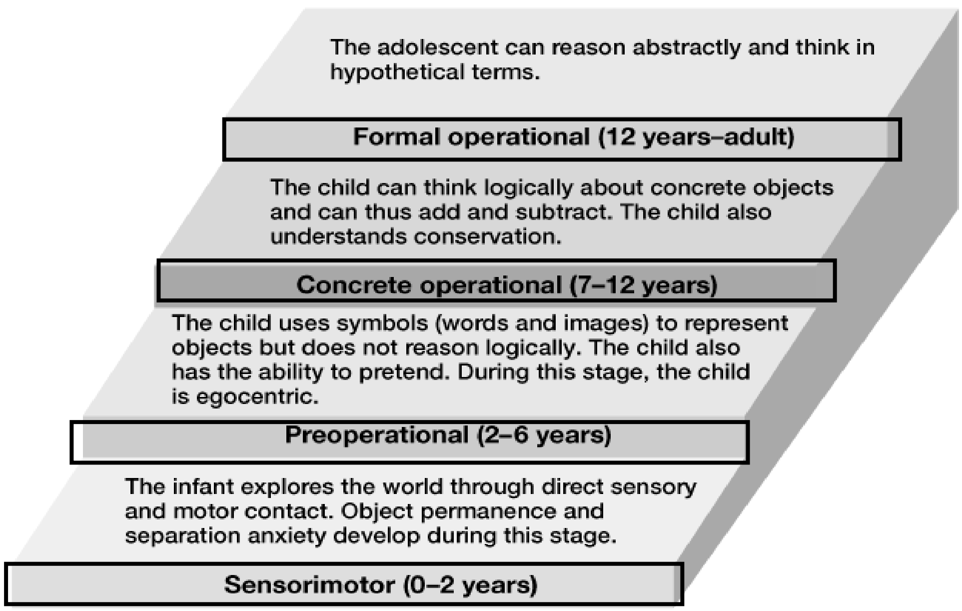


Figure 2.5 Piaget's Stages of Cognitive Development (1964).

Recent studies investigating Piaget's model of cognitive development have found that while his sequencing of cognitive stages were correct, the corresponding age boundaries were not. Research carried out by Shayer and

Adey (1981) and Shayer et al. (2007) in the U.K. and Childs & Sheehan (2010) in Ireland have shown that the majority of the pupils at second level and students at third level have not reached the ‘expected level’ of cognitive development as originally predicted by Piaget. Piaget’s age predictions for learners in the formal operational and concrete operational stages of development were widely optimistic for the diverse second and third level populations in today’s classrooms. It is evident that Piaget’s findings are based on an elite cohort of learners. Most third level students may still be operating at the concrete stage of cognitive development, making the abstract thinking required in Science and Mathematics almost impossible for these students.

2.4.2.2 The Information Processing Model

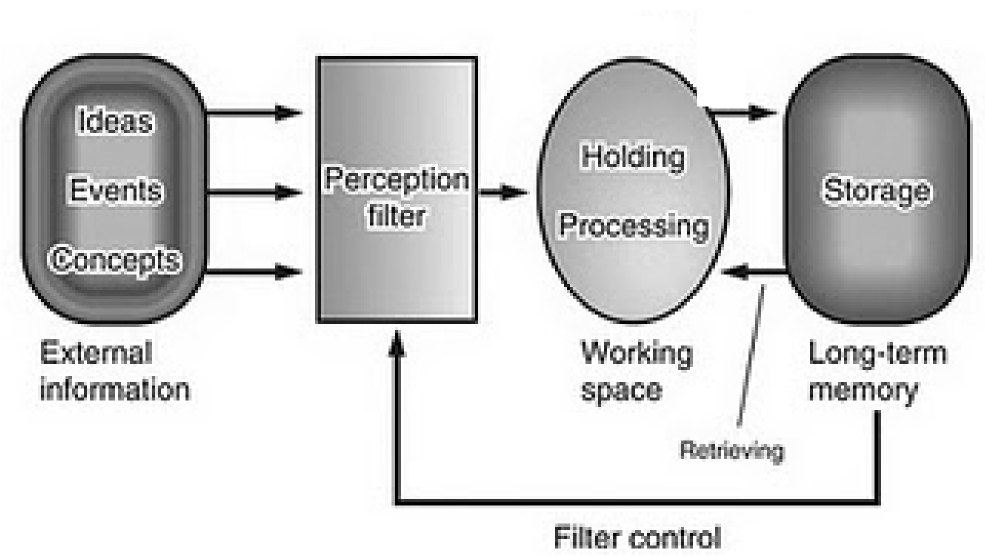


Figure 2.6 The Information Processing Model. (Johnstone, 1997)

This Information Processing Model (Figure 2.6) provides a clear insight into how students perceive, understand and learn information. Even though each learner is unique, it is important to understand that essentially we all learn in the same way (Reid, 2008). The learner selects some of the information presented to them, and where possible, links are made with prior learning as the learner works to solve or understand the problem, applying what they already know. This cognitive model also acknowledges the affective factors involved in learning.

Each stage of the model will now be discussed individually, in order to understand how each stage is linked to each other. Johnstone (2000b) highlighted the importance for teachers and lecturers to understand the processes of learning, rather than the development of more programmes and courses to teach Chemistry. Johnstone (1997) outlined learning as the reconstruction of material from the teacher to the learner. He described it as an *'idiosyncratic reconstruction'* of what the learner understands of the new material, taking into consideration their existing knowledge, beliefs and misunderstandings.

<u>a) Perception Filter:</u> The perception filter is the fundamental component of the Information Processing Model. Since the learner can only perceive what is familiar to them, if a new concept is rejected at this stage, it may never pass through into the Working Space and then into Long Term storage and understanding. The perception of new information is dependent on what the learner already knows. Even though the teacher can provide stimuli for the learners, the learners' previously developed knowledge and concepts are used to activate and control their perceptual filter (Johnstone, 1997). When there is no attachment to established frameworks in the Long Term Memory, this often forces the learners to rote learn. The efficient use of the perception filter reduces the risk of overload in the Working Memory Space.

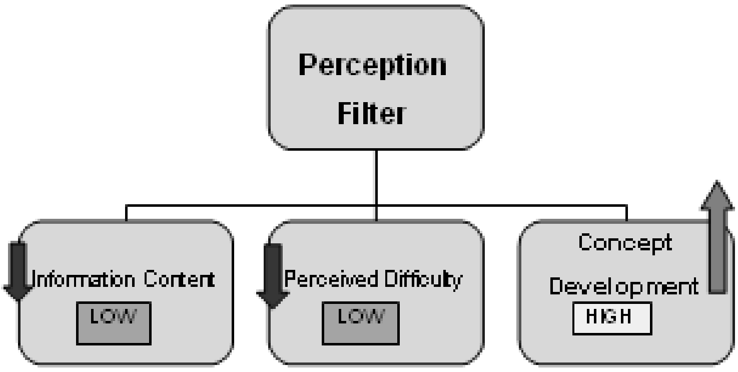


Figure 2.7 Most ideal conditions for a learner to perceive a problem (Johnstone, 1981).

The three main factors contributing to a learner’s perception of a problem are shown in Figure 2.7. These three factors are interdependent. The ideal condition for a learner to perceive a problem is when the information content and perceived difficulty of the task is low, while the development of the concept is high. Conversely, a combination of other conditions will not facilitate the learner’s perception and approach to the problem. Problems are most likely interpreted by the learner as difficult due to high information load.

The perception filter is controlled by the Long Term Memory. Ausubel (1968) explained how our prior knowledge and experiences affect what we can learn in the future. Pre-learning exercises such as pre-lectures and pre-laboratory sessions are of greatest benefit to learners with no previous Chemistry knowledge (Reid, 2008; Seery, 2011). This pre-learning enables the perception filter to work more efficiently, as it provides the learner with a related concept to link with from the Long Term Memory. This means that information can be easily retrieved if it has been stored in a linked and orderly fashion. Visual or symbolic storage of information can often facilitate their retrieval (Reid, 2008). An expert (teacher/lecturer) can look at a problem, ignore the ‘noise’ (irrelevant details) and retrieve the associated concept (‘the signal’) from the Long Term Memory to further develop the new concept or create a link to the established framework. However, none of this is as easy for the novice learner. Witkin and Goodenough (1981) identified the importance of selecting what is important in a particular task from all of the information given. This is called ‘Field Independence’. Learners who are Field Independent are less distracted by irrelevant material and can focus sharply on the ‘signal’, the message being taught. If this Field Independence is coupled with a High Working Memory space, through the development and use of learning strategies such as chunking, the learner can perform to their greatest ability (Johnstone, 2006). (Chunking will be explained when discussing Memory Overload). Conversely, a pupil who is highly Field Dependent and has a low Working Memory Space will have a lower performance level. This inter-relationship between Field Independence and Working Memory space is illustrated in Figure 2.7. Material needs to be presented to the learner in a simple and clear manner to reduce the risk of overloading the Working Memory Space (Reid, 2008).

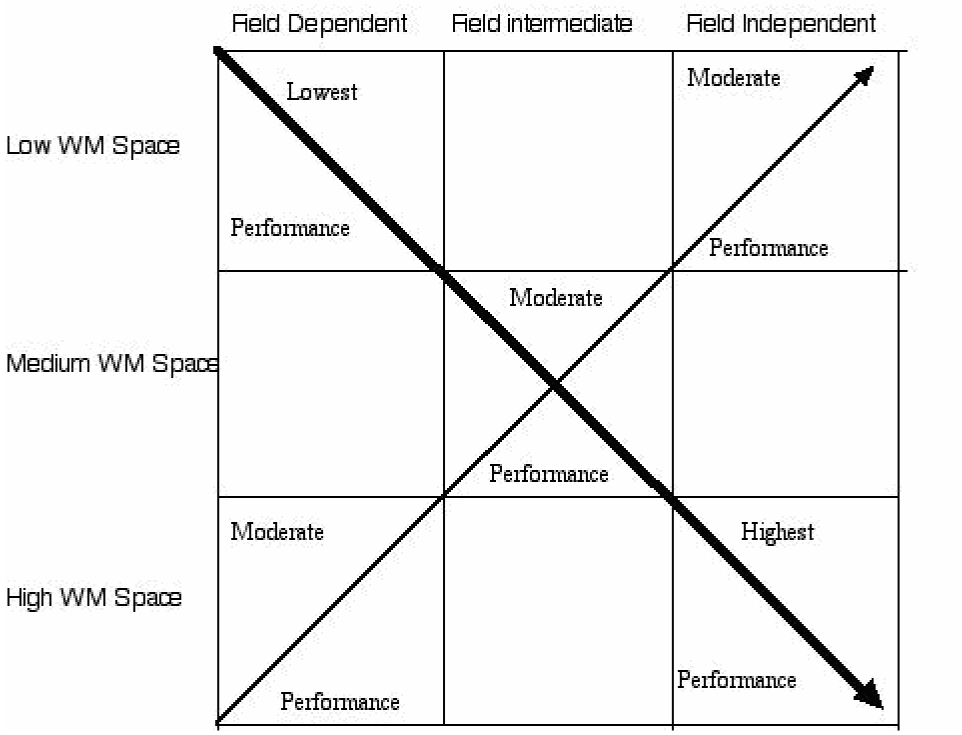


Figure 2.8 Effect of Working Memory Space and Field Independence on Chemistry performance (Johnstone, 2006)

<u>b) Working Memory Space & Memory Overload</u>: Interpreting, re-arranging, comparing and preparing all happen within the Working Memory Space. This space is also the Short Term Memory storage space. For this reason, it is easy to understand how a problem or new information presented to the learner can limit their working space available, if the information is not presented in an approachable manner. Johnstone and El-Banna (1986) report that the maximum number of pieces of information that one can hold within this Working Memory space is seven. The Digit Backwards Test (DBT) and Figure Intersection Test (FIT) were used to measure Working Memory space. However, it is important to acknowledge that this is only true when no processing is required. This Working Memory Space is shared between holding and processing of information (Johnstone, 2010). If there is too much of either, the other function is restricted. Working memory space increases with age reaching a maximum at an average age of 16. Due to the nature of the difficulty of Science and the method by which it is taught, the average

number of pieces of information that can be stored in the Short Term Memory is five (Johnstone and El-Banna, 1989).

Unless there is systematic organisation of information from the Working Memory Space to Long Term Memory, any new ideas can displace older ideas. This can lead to confusion and memory overload. Johnstone and El-Banna (1986) examined questions given to learners by the demand (Z) involved in answering the question. The information given in the question needs to be processed, stored information in the Long Term Memory may need to be recalled and learned strategies for answering the question need to be activated.

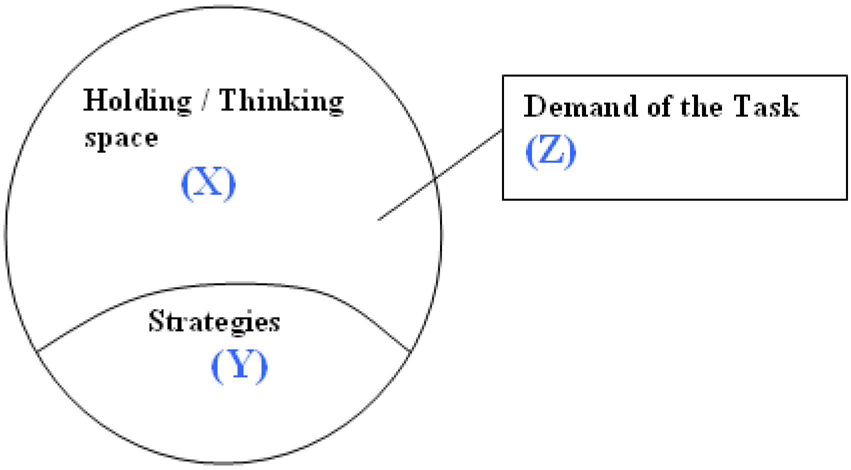


Figure 2.9 Simplified Model of Working Memory Space (Johnstone and El-Banna, 1986).

Figure 2.9 shows the three factors contributing to our use of the Working Memory. To avoid overloading of the Working Memory and a decline in performance, the difficulty of the task (Z) cannot exceed the Working Space capacity (X) (Johnstone and El-Banna 1986). When Z ≤ X, this allows a fair assessment of the pupil's knowledge, and performance will therefore relate to the pupil's knowledge and skill, irrespective of their Working Memory capacity. A beginner needs tasks to be set below their capacity (Z<X). However if Z > X, the pupil's performance is limited by their Working Memory capacity. This is where the use of strategies (Y) are constructive. The appropriate application of learned strategies such as formulae, definitions, mnemonics etc. can reduce the task demand and so enable the pupil to answer the question. As strategies are developed, tasks can be set with a higher demand (Z).

Our working space capacities cannot expand beyond their limit (X). However, we can train the working space so that we can use it more efficiently. If the overall demand of the question exceeds the capacity of the Working Memory Space this leads to memory overload and performance falls. This hypothesis was presented by Johnstone and El-Banna (1986) and reviewed by Johnstone (2006) and proposes that strategies can be developed and learned to overcome the learners' capacity limitations. The teacher should think more closely about how a question is asked as well as limiting and excluding the noise in the teaching situation, in order to facilitate the learners' recognition of the signal. It is important for teachers to realise that in this situation, they often don't 'hear the noise' because they are used to it, and know what needs focusing on. Most introductory Chemistry textbooks introduce on average 15 concepts, symbols and terms per page (Rowe, 1983). It is no surprise then, that the learners' Short Term Memory can easily become overloaded when attempting to study Chemistry. Reid (2008) referred to the work of Johnstone and Kellet (1980) in their identification of Information Load as the number of pieces of information that a non-expert learner can hold, while performing a task successfully at the same time. The complex nature of Chemistry which requires multi-level thought is another contributing factor leading to overload of the Working Space.

In many cases, teachers incorrectly estimate their learners' level of ability and prior knowledge. This, as well as the complex nature of Chemistry, contributes to memory overload for the learner. Johnstone (1981) suggested the use of 'crutches' such as rules and mnemonics to allow the learner to build confidence in the topic. These can be removed later when the concept is more clearly developed. For example, the use of the $M_1V_1/N_1 = M_2V_2/N_2$ formula for the titration calculations, which is a simple and proven method for beginners to learn and use before a more developed understanding of molarity is gained. However, there is a danger that some students never give up their 'crutches' and thus never fully develop an understanding of a topic.

‘Chunking’ information is a strategy used to maximise the space available in the Short Term Memory. For example, the letters FBI, CSI, ISPCC etc. are easily chunked and stored as one piece of information rather than three or five separate pieces. However, each of these acronyms are easily recalled because they are familiar to us. Learners are unable to chunk information which is unfamiliar to them. As learners develop their own strategies, the appropriate application of these devices will allow them to outperform their Working Memory capacity. The time needed to chunk information is generally between 5-10 seconds per chunk. However, the pace of a general lecture is usually much quicker than this. This explains how many students may feel lost and disinterested in Chemistry lectures. The time taken to chunk information also depends on how familiar the information is to the learner. Since beginners have fewer relevant concepts in Chemistry, which help to file their information efficiently, they may experience an overload of the Short Term Memory sooner than a more experienced learner in the subject. The rate at which information can move through the Short Term Memory depends on the familiarity of the new information and degree of connectedness among the ideas coming in and previous knowledge. Mental lapses happen sooner when the information that has to be learned seems to form no pattern. Rowe (1983) described four types of mental lapses that can happen: short-term memory overloads, the use of symbols which are not familiar to the learners, momentary confusion (as the learner tries to make sense of new information before processing to the Long Term Memory) and when something the lecturer says initiates a complementary chain of thought. All four of these mental lapses result in the learner missing out on the continuing lecture.

Reid (2008) suggested the following guidelines to reduce the load on the Working Memory Space: change the teaching order, modify the speed and sequencing of lessons and to break down complex areas to facilitate the human psychology of the Information Processing Model.

<u>Long Term Memory:</u> The feedback loop from the Long Term Memory to the Perception filter provides an insight into the work of Ausubel (1968). Previous

knowledge directly influences the learners' perception of new material and their ability to understand and store it. The ability to recall and retrieve information from the Long Term Memory depends on how this knowledge has been stored. The accuracy of our prior knowledge can affect the quality of the new information which is constructed and linked to previously developed frameworks. The way in which information is stored in the Long Term Memory has consequences for future learning. Johnstone (1997) discussed and applied Ausubel's Spectrum of Learning, which is illustrated in Figure 2.10. The Spectrum of Learning ranges from meaningful learning to rote learning.

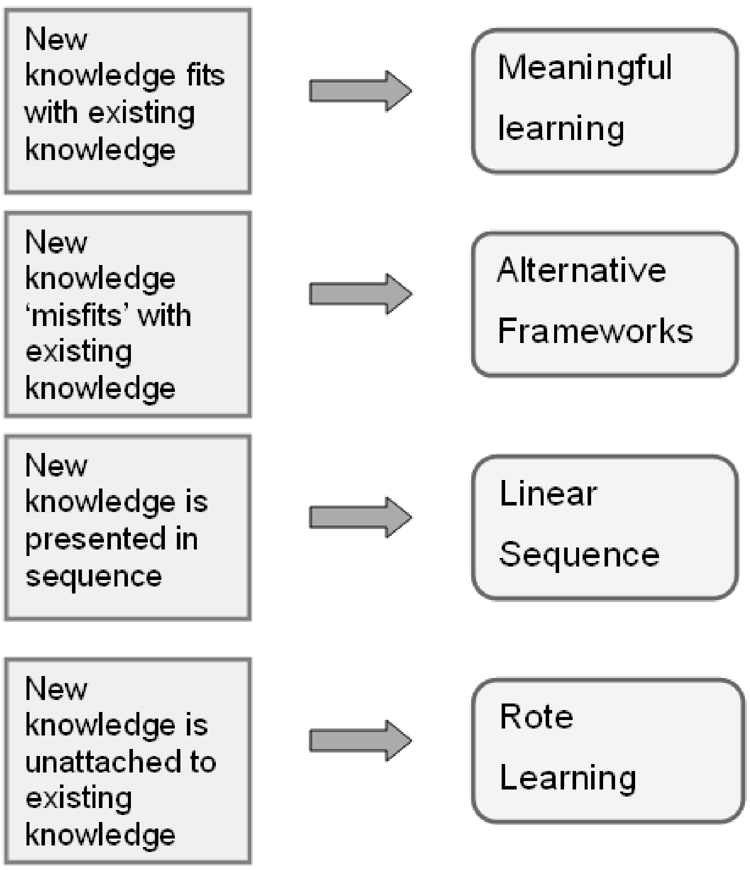


Figure 2.10 Ausubel's Spectrum of Learning (Johnstone 1997).

Figure 2.10 illustrates the different ways in which information can be stored in the Long Term Memory (Johnstone, 1997). New information can be merged with other information, which allows for meaningful learning. Alternative frameworks lead to the development of misconceptions which are difficult to undo. Information which is rote learned is mostly unattached to any pre-existing facts and therefore difficult to recall later and has a short lifetime (Johnstone, 2006). While some information is unattached to previous knowledge, this may also be as a result of no pre-existing knowledge. Incorrectly linked knowledge or separate fragments of knowledge in the Long Term Memory are stored by memorisation without any clear understanding. This can lead to a lack of intrinsic satisfaction for the learner, and so cause a negative attitude towards learning Chemistry (Reid, 2008). Chemical misconceptions will persist when the cognitive organisation of the knowledge is poor. Teachers need to present material in a manner to prevent overload and to optimise the processing stage to facilitate long term storage (Johnstone, 2006). Ausubel's spectrum can be applied to validate the practice of priming and preparing the Long Term Memory through pre-laboratory and pre-lecture sessions. Pre-problems activate the Long Term Memory to facilitate the solving of real problems later. This model of learning also highlights the negative consequence of misconceptions stored in the Long Term Memory.

Having looked at how the Information Processing Model works and the different stages involved in learning, it is also important to consider the 'ideal learning environment' that teachers should aim to create to facilitate teaching and learning.

As well as using teaching strategies (Y) so that tasks of higher demand (Z) can be kept within the learners' capacity (X), it is important for the teacher to encourage the learner to develop their own strategies to allow the individual to out-perform their own limitations (Johnstone and El-Banna, 1986).

Reid (2008) outlined ways of increasing pupils' levels of understanding in Chemistry. These ways include pre-learning helps to improve the selection process of the perception filter as pupils become more field independent; presenting a problem in a way which is clear to the learner can facilitate linkages with prior learning e.g. the use of a picture from a laboratory experiment may trigger a concept previously developed in the Long Term Memory; deliberately linking new material to old material increases pupil understanding.

2.5 Teaching and Learning Approaches

The diversity in the student population in recent times calls for a more varied approach to teaching and learning. Cottrell (2000) states that

'*Student intakes today are more likely to have higher proportions of students who learn best if they are offered alternative ways of studying'*.

2.5.1 Teaching Smarter

To enhance the students' learning experience other teaching and learning techniques need to be explored rather than traditional ones. In today's teaching climate, it is important to identify at-risk students and create a supportive learning environment. By teaching smarter, rather than teaching harder, students are given the opportunity to succeed (Perkins, 2007). There are a number of ways that this can be achieved.

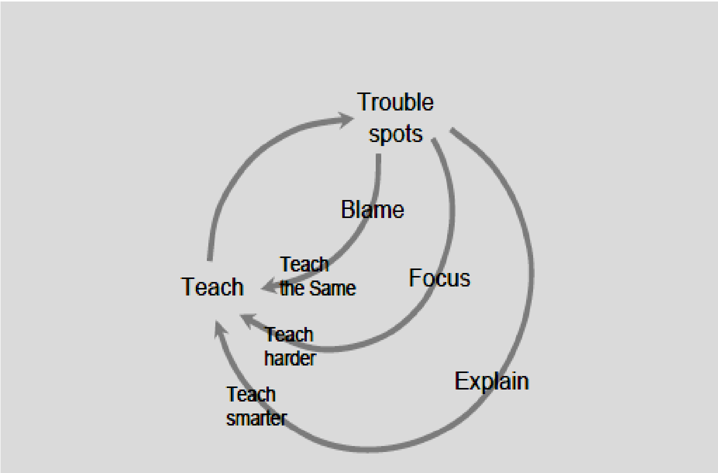


Figure 2.11 Trouble Spots in Learning (Perkins, 2007).

It is clear that students at third level have difficulty learning and understanding Chemistry. Childs (2009) referred to Perkins' (2007) "Theories of Difficulty" (Figure 2.11). There are three optional responses for the teacher on identifying the learners' difficulty with a particular topic:

Teach the same- Blame the student and carry on teaching in the same manner.

Teach Harder - Focus on the difficult areas and spend more time on them.

Teach Smarter – Look at why students find these topics difficult and develop a better way of teaching to facilitate understanding.

Teaching smarter involves diagnosing the areas of difficulty that learners have with a difficult topic and trying to teach that topic in a different manner to alleviate the misconceptions or difficulties. Such a strategy has been carried out by many educators in the teaching of Chemistry and some of the approaches are described below.

2.5.2 Inquiry-Based Approach

Inquiry-based approaches to Science education focus on student-constructed learning as opposed to teacher-transmitted information. Inquiry implies involvement that leads to understanding and involvement in learning and possessing skills and attitudes that allow you to seek answers to questions while you construct new knowledge. Unfortunately, our traditional educational system has worked in a way that discourages the natural process of inquiry, students become less prone to asking questions. An inquiry-based curriculum has been shown to develop independent and critical thinking skills, positive attitudes and curiosity toward Science and increased achievement in biological content (Hall & McCudy, 1990).

For students to engage in inquiry in a way that can contribute to meaningful learning they must be sufficiently motivated. The challenging and extended nature of inquiry requires a higher level of motivation on the part of learners than is demanded by most traditional educational activities. To foster learning, motivation must be the result of interest in the investigation, its results, and their implications. When students are not sufficiently motivated or are not motivated by legitimate interest, they either fail to participate in inquiry activities or they participate in them in a disengaged manner that does not support learning (Edelson *et al.,* 2004). Inquiry-based learning also makes greater demands on the teacher compared to the traditional didactic approach.

Introducing inquiry-based strategies not only into the classroom/ lecture theatre but also into the laboratory sections of Science courses will help students enhance and develop their critical-thinking and communication skills. The following list outlines benefits that students can gain from inquiry-based teaching and learning.

- Develop critical-thinking skills
- Become actively involved in the learning process
- Experience excitement about studying Science because rigorous problem-solving can be enjoyable
- Work together as part of a problem-solving team
- Increase self-esteem from the fact that their own individual effort contributes positively to the team solution of the problem
- Develop problem-solving skills that can be applied to other areas in their lives and to other academic disciplines
- Learn how to design an experiment and carry out scientific research including observations and data handling
- Learn how to organize and interpret scientific information.
- Make written and oral presentations of the results of their research
- Increase understanding of basic scientific knowledge through deductive reasoning rather than passive learning techniques.

(Kahn & O'Rourke, 2005)

2.5.3 Problem-Based Learning

Problem-based learning (PBL), encourages and motivates students to 'learn to learn' (Duch, 1995) and challenges them to take charge of their own learning. In the majority of Universities, the lectures are the central feature for students' learning, however the lecture environment often rates poorly as a means of motivating students. The main aim of the lecture is for the lecturer to present a body of set material to the students. However, effective student learning does not necessarily result from the lecturer having covered the material. It seems that no matter how well the lecturer performs during the course of the lecture, most of the time students still sit passively writing notes and are seldom involved (Margetson, 1994). The lecture is then traditionally followed by a tutorial or laboratory session. It is in these sessions where the students are encouraged to participate, but often similar non-participation rates are observed. Students in tutorial and laboratory sessions find that they are required to meet unrealistic workloads which often lack intellectual challenge and does little to motivate them. Further, subject-based learning means that subjects are viewed in isolation from each other and it is the subject that is driving learning. This style of learning assumes that the learner has little knowledge and the instructor is the source of knowledge (Woods 1994). PBL causes a shift from the traditional higher education focus, the lecture. No longer is the lecturer the transmitter of facts, delivering a body of knowledge (Kiggins, 2007). The tutor in PBL becomes a facilitator and must be prepared to ask open-ended questions, monitor progress, probe, encourage critical reflection, and make suggestions and help students to create a positive learning atmosphere which by definition alone, requires a high level of interpersonal skills (Margetson, 1994). Barrows (1986), states that the mark of a successful tutor is knowing when to intervene, not interfering too much in the group process and asking questions.

The critical difference in PBL is that it is characterised by instruction which involves students working in small groups to solve ‘real world’ problems, (Duch, 1995). It is important to note that PBL is mainly used at third level and can be considered as resource intensive as it usually requires small groups working with a tutor. Some examples of PBL applied to Chemistry are the use of a diverse range of assessment activities for example peer assessment. Belt *et al.* have developed PBL resources for analytical chemistry putting industrial, pharmaceutical, environmental and forensic chemistry into context for students. As well as providing valuable outcomes, these resources also provide a set of transferrable skills. Green Chemistry has also been used as a context for chemistry where the main outcome is to raise awareness of green chemistry as it relates to the chemical industry (Overton, 2007).

2.5.4 Diagnostic Testing

Diagnostic testing is an important tool for educators who want to know where their students are academically in order to bring those students to where they need to be. Multiple-choice tests are often more preferable in Science classes since they are easy to apply and evaluate students’ understanding of the related subject; however, multiple-choice tests have some limitations such as determining whether a student gives a correct response to a test consciously or just by a chance. On the other hand, interviews can give more detailed information about students’ alternative conceptions and their understanding on a particular concept, but a large amount of time is needed to conduct interviews with many students for generalizing their alternative conceptions (Cetin-Dindar & Geban, 2011).

As these techniques have some limitations for practical use in classes, diagnostic tests are proposed to identify students' alternative conceptions (Treagust, 1986, 1995). A diagnostic test measures where a student is in terms of his/her knowledge and skills. It assesses the abilities of a student to solve problems, answer questions and to assess strengths and weaknesses in a subject area. By using diagnostic instruments at the beginning or on completion of a specified topic, Science teachers/lecturers can achieve better understanding about the nature of students' understanding and the existence of any alternative conceptions or misconceptions in a particular topic being studied. Once students' alternative conceptions are identified, Science instruction can be modified to remedy the problem by developing and/or utilising alternative teaching approaches that specifically address students' misconceptions. Research evidence also suggests that experienced teachers frequently do not appreciate the problems encountered by students in learning complex Science concepts. There are two reasons for this. First, normal approaches to instruction do not probe sufficiently for the students reasoning in their answers. Second, the usual assessment procedures do not demand such detailed explanations of concepts from students.

However, the use of diagnostic instruments and the subsequent change in teaching strategies does not guarantee that alternative conceptions will not be constructed and retained by students. One way to encourage more students to study Science is by presenting Science to them in such way that, through the teachers' planned formative assessment, students can begin to question and understand the underlying Science concepts. Through this teaching approach, students will be encouraged to think about the concepts and consider alternative explanations rather than memorise basic facts for a test or examination which are then forgotten.

The use of diagnostic instruments in teaching as a means of planning formative assessment will also enable teachers to diagnose students' misconceptions and understanding in particular areas as well as serving as a means of remediation prior to any summative assessment. Through cooperative group work as well as a variety of individual learning opportunities, teachers can help students examine their own understanding. When used effectively, these tests and their follow-up can contribute to students' deeper understanding of the Science concepts in the curriculum.

2.5.5 Formative Assessment

Formative assessment is about assessment for learning as opposed to summative where assessment is of learning. It refers to assessment that is specifically intended to generate feedback on performance to improve and accelerate learning (Sadler, 1998). The goal of summative assessment is to measure the level of success or proficiency that has been obtained at the end of an instructional unit, by comparing it against some standard. Formative assessments check for understanding along the way and guide teacher decision-making about future instruction; they also provide feedback to students so they can improve their performance. Formative assessments help to differentiate instruction and thus improve student achievement.

When teachers know how students are progressing and where they are having trouble, they can use this information to make necessary instructional adjustments, such as re-teaching, trying alternative instructional approaches, or offering more opportunities for practice. These activities can lead to improved student success (Boston, 2002).

2.5.6 Blended Learning

Blended learning is the combination of multiple approaches to learning. Blended learning can be accomplished through the use of 'blended' virtual and physical resources. A typical example of this would be a combination of technology-based materials and face-to-face sessions used together to deliver instruction. In the strictest sense, blended learning refers to any situation where a teacher combines two methods of delivery of instruction. Figure 2.12.

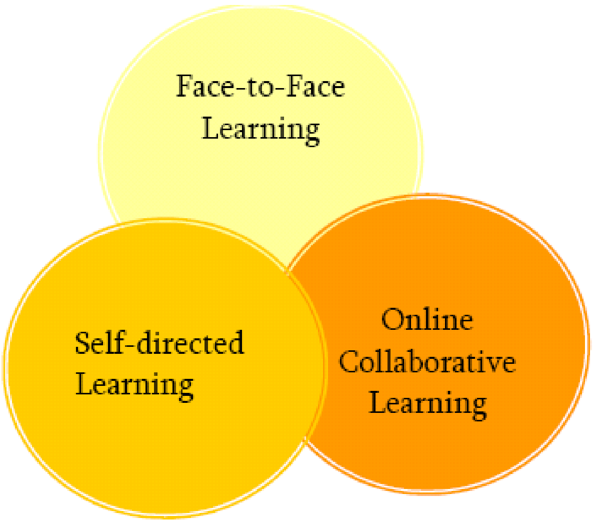


Figure 2.12 Elements of Blended Learning
(Purcell, 2010)

> "*Blended learning describes learning activities that involve a systematic combination of co-present (face to-face) interactions and technologically mediated interactions between students, teachers and learning resources*" (Bliuc *et al*., 2007).

A variety of delivery methods offers the best of both worlds, combining any time/place/pace advantages with opportunity for teacher contact and support. Blended learning programmes can be tailored to the students' specific needs and therefore support learning styles for the students. It can improve the quality of the learning experience through:

- Individualised learning experiences for all learners including those who are weaker in a subject area
- Personalised learning support
- Collaborative learning
- Flexible study, with learning on demand, anywhere or anytime, to meet students' needs
- Wide access to digital resources.

Individuals acquire knowledge and skills through a blend of many different experiences such as reading, observation, collaboration, trial and error, guided practice, application and experimentation. The same learning principles should be built upon in the development of a blended learning programme if they are to be successful. The various elements of learning should be viewed together as one solution. Meaningful connections between teaching and learning and e-learning content, will lead to a more robust programme which maintains and supports motivation. Learning programmes that effectively blend multiple learning strategies and styles represents the very best of traditional teaching methods for the future (Gulc, 2006). Blended learning can be incorporated into a Science course of study in a number of ways including online quizzes with an instant feedback feature, animations and stimulations to aid understanding and links to tutorial notes and questions. Williams *et al.* (2008) used a blended learning approach with students from a level 2 inorganic Chemistry module where lectures were replaced with study packs and were supported by formative online assessment through 'Blackboard'. The online assessment feature was designed to allow for rapid feedback for the students. Results showed an improvement in student performance in module exams in comparison to other years as well as an increase in student satisfaction in subject content and delivery and performance feedback. In a study carried out by Lovatt *et al.* (2007) which investigated student engagement with two learning supports in their first year of study. One of these learning supports included online resources on 'Moodle'. It was shown that students who interacted with the available online resources performed better in their terminal exam. Also, students identified ease of use and accessibility as positive aspects to the course. Lecture notes, tests and quizzes and tutorials were the most accessed resources.

2.6 Attitudes towards Science

A common definition has described attitudes as including the three components of cognition, affect, and behaviour. Reid (2006) defines these components:

(1) A knowledge about the object, the beliefs, ideas component (Cognitive)

(2) A feeling about the object, like or dislike component (Affective)

(3) A tendency-towards-action, the objective component (Behavioral)

This appears to be a realistic and identifiable view of attitudes because these components are so closely linked together. For example, some students have knowledge of Science (cognitive) and therefore have a feeling or an opinion about it (affective) that may cause them to take some actions in this case whether they decide to study Science (behavioral). It has been reported that there is a decline in positive attitudes towards Science as student's progress through secondary school whereas positive attitudes have been associated with interest in and enjoyment of Science among students at secondary school.

Cleaves (2005) examined the formation of choices over three years among higher achieving students with respect to enrolment in Science courses. It was discovered that the situation regarding Science choices is a combination of self perception with respect to Science, occupational images of working scientists, relationship with adults and perceptions of school Science. Among other things, she found that students thought that the curriculum was irrelevant and that Science teaching seemed to be limited to preparing students for a research career in Science at University level. This clearly shows the need for a change in the Science curriculum to get students motivated and passionate about studying the subject. In order to ameliorate the low levels of participation in Science subjects at senior level it is imperative to make the curriculum more appealing to potential Science students (Millar, 1996).

Barmby *et al*. (2008) conducted research in England examining the variety of attitudes towards Science over the first three years of secondary schooling. The study involved a 'Lab in a Lorry' project and involved analysing 932 student's attitudes towards Science. From the results, two main patterns were clear. Firstly student's attitudes towards Science declined as they progressed through secondary school and secondly the decline was most pronounced for female students. They list the following as the most prevalent reasons why students do not enjoy Science:

- Science is not perceived as being well explained
- Science is not perceived as practical
- Science is not perceived as relevant.

These findings highlight the issues concerning student attitudes and perceptions. Attitudes to Science have also been discussed in other studies including George (2006) and Osborne *et al.* (2003), which have looked into the varying attitudes of students towards Science and the prevalent reasons behind these attitudes. In attempting to change these negative attitudes, it is fundamental to change student's experiences of the subject, which would as a result give them a much more positive outlook. It has been reported that students regard Science as overloaded with content and not generally related to working life. If students cannot link the Science that they learn with their everyday lives and personal experiences it is unlikely that they will enjoy studying it, as they will feel no real connection with the subject.

Much of the research conducted points towards the fact that student's attitudes towards Science itself are positive. A large scale market research survey conducted in the United Kingdom, based on a sample of 1552 students aged between 14-16, found that students saw Science as useful (68%) and interesting (58%). Also a large proportion of those surveyed saw the relevance of it as a reason for studying it (53%) and that it offered better employment prospects (50%). 87% of students rated Science as 'important' or 'very important' (Research Business, 1994). In contrast to these views expressed, Stables (1996), discovered many stereotypical views of scientists among secondary school students. This will have an influence on students when it comes to subject choice and give a negative slant on studying Science subjects Biology, Physics or Chemistry.

The decline in the number of students choosing to study Chemistry at Leaving Certificate level is a well known problem in Ireland in recent times. The main reason that has been put forward for this decline is the lack of interest shown by students in the physical Sciences. Research conducted by Regan and Childs (2003), which consisted of a survey of 88 second level students, showed that 71.6% of students considered Biology to be the most interesting Science, the Physical Sciences (Physics and Chemistry) showed quite a different picture. The least popular Science is physics with 62.4% of the students considering it the least interesting of the Sciences and only 8.2% considering it interesting. Chemistry was considered least interesting by 32.9% of the sample and most interesting by 21.2%.

The Task Force Report on the Physical Sciences (2002) makes wide ranging recommendations involving substantial investments in equipping laboratories and providing lab technicians to teachers.
The main aims of the Task Force were;

- To devise and recommend additional measures to address the issues of low take-up rates.
- To consider how physics and Chemistry can be most effectively promoted among students particularly those at Junior Certificate Level.
- To review the impediments to the selection by students of the physical Sciences as second level subjects and as options at third level.

In order to promote Chemistry and make it a more appealing subject for not alone students to study but also for teachers to teach, The Task Force also addressed issues in the following areas:

- The support and promotion of high quality teaching provision in the physical Sciences as well as awareness of the career opportunities open to students.
- The identification of how third level institutions can assist with the promotion of the subjects, skills up-grading and in-service training of teachers.
- The support and promotion of a strengthening in the contacts between physics and Chemistry Departments and Education Department within Universities and also their interaction with teachers and students in schools.
- The increase in involvement of industry in the promotion of physics and Chemistry in schools and as career choices.

Following the findings of the Task Force Report, a number of actions were suggested to tackle the problems identified. These were the implementation of competitions and projects, promotional activities in schools such as Chemistry Magic Shows and Science Clubs, relevant career information, open days, production of teaching resources, investment in in-service training of teachers, refurbishing and equipping school laboratories and providing technical assistance to Science teachers. It was proposed that these measures would all help to promote Science and increase the number of students choosing to study it. Student attitudes and confidence levels can have a major impact on student performance in Chemistry and it seems that their attitude and confidence are developed when they first start to study Science.

2.7 Previous work in Helping 'At-Risk' Students

This study is a follow on of a pilot project done in the University of Limerick in 2009 by Hayes and Childs (2010). This pilot study involved the development of an Intervention Programme for two groups of students identified as low-achievers. This programme sought to use the students' prior knowledge and misconceptions, identified through diagnostic testing, to develop a course of tutorials for the students that specifically targeted these areas of difficulty. The programme proved to be moderately successful and those students who participated in the Intervention Programme improved their score in the post-test. Due to these positive results, it was decided to expand the programme and it is the expanded intervention that is discussed in this document.

Chapter Three

Methodology

3.1 Introduction

This chapter outlines the data collection techniques used, a description of the sample groups as well as information on the design and implementation of the pre- and post-diagnostic tests and attitude and confidence tests used. It will also provide information on how the Intervention Programme was developed in Phase 1, Phase 2 and Phase 3.

3.2 Structure of the Investigation

This investigation is divided into three Phases: Phase 1, Phase 2 and Phase 3. As mentioned in Section 2.7, this study is a follow-on to a pilot study carried out by Hayes and Childs 2010. Due to the positive results of the pilot study, it was decided to repeat the Intervention Programme, but this time to expand the scope of the programme. Taking into account some of the limitations of the pilot study, an expanded Intervention Programme was devised. Due to high failure rates in certain Chemistry modules, it was decided to develop an Intervention Programme which would reduce the high failure rates among these students by improving their chemical understanding. The programme involved a blended learning approach, which included a combination of face-to-face teaching and learning each week, as well as online resources and elements of formative assessment. Attendance at the Intervention Programme tutorials was voluntary for the students. The first implementation of the Intervention Programme was in semester 1 of second year (Phase 1) and it was then decided to target students earlier so Phase two began in semester 2 of first year. Table 3.1 provides an overall timeline of each of the three Phases of this project. At the time of the Intervention Programme, no other tutorials (besides tutorials which were linked to their current Chemistry module) were available to 1st year students who had not studied Chemistry before. Before the Intervention Programme was developed, the author had an informal meeting with Dr. Claire McDonnell who lectures in the School of Chemical and Pharmaceutical Sciences, Dublin Institute of Technology. Claire and her colleague Dr. Christine O' Connor were providing extra support for students who had not previously studied Chemistry. This extra support included tutorials with the students. The results were very positive and there was an improvement in the Chemistry pass rate. A reduction in the student/tutor ration also had an effect on the success of the programme. Following this meeting, aspects of this extra learning support were incorporated into the Intervention Programme.

Both quantitative and qualitative methods were used during this study as they allow statistically reliable information obtained from numerical measurement to be backed up by information about the research participants' explanations. Quantitative methods are those which focus on numbers and frequencies rather than on meaning and experience. Quantitative methods (e.g. pre- and post-diagnostic tests) provide information which is easy to analyse statistically and fairly reliable. Qualitative methods are ways of collecting data which are concerned with describing meaning, rather than with drawing statistical inferences. What qualitative methods (e.g. interviews) lose on reliability they gain in terms of validity. They provide a more in depth and rich description. Figure 3.1 shows the methods used to assess the impact of the Intervention Programme.

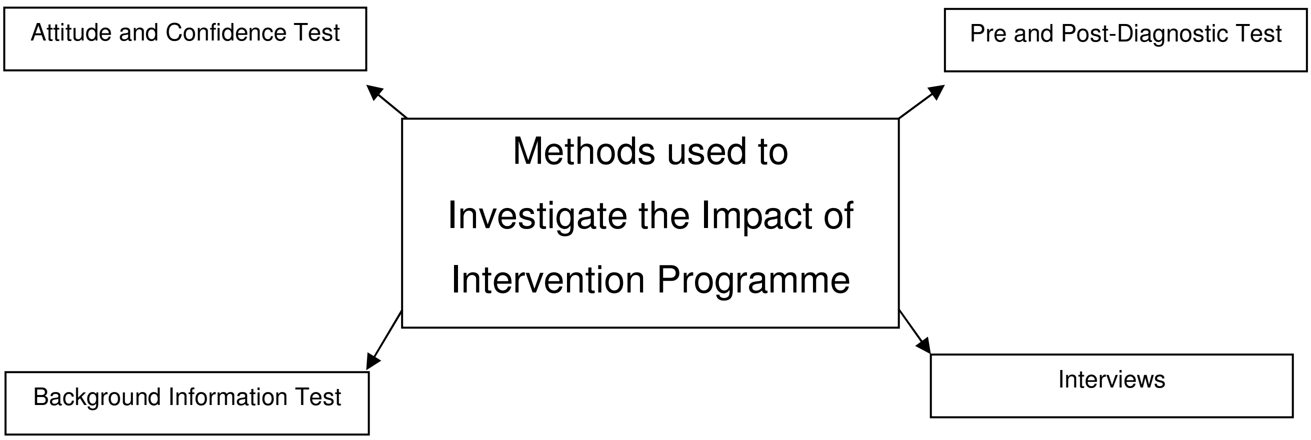


Figure 3.1 Methods used to investigate the impact of the Intervention Programme.

Table 3.1 Timeline for Three Phases of Intervention Programme.

	Date	Schedule
Phase 1 (Year 2, Semester 1)	Sept. 2009 to Dec. 2009	• Application for Ethical Approval • Preparation of Diagnostic Test • Preparation of Attitude and Confidence Test • Advertise tutorials to three target groups • Contact students regarding timetable • Organise available tutorial slots for all three groups • Organise rooms for tutorials • 10 weeks of tutorials including testing on first tutorial session
Phase 2 Part 1 (Year 1, Semester 2)	Jan. 2010 to May 2010	• Advertise tutorials to three target groups • Contact students regarding timetable • Organise available tutorial slots for all three groups • Development of online resources • Organise rooms for tutorials • 10 weeks of tutorials including testing on first and last tutorial sessions • Updating of online resources
	May 2010 to Sept. 2010	• Organise results from Phase 1 • Prepare diagnostic tests for Phase 2 • Contact students regarding timetable
Phase 2 Part 2 (Year 2, Semester 1)	Sept. 2010 to Dec. 2010	• Organise available tutorial slots for all three groups • Organise rooms for tutorials • 9 weeks of tutorials including testing on first and last tutorial sessions • Updating of online resources • Select Students for Interviews • Carry out Interviews
Phase 3 (Year 1, Semester 2)	Jan. 2011 to May 2011	• Advertise tutorials to three target groups • Contact students regarding timetable • Organise available tutorial slots for all three groups • Organise rooms for tutorials • 10 weeks of tutorials including testing on first and last tutorial sessions (same as Phase 2, part 1) • Updating of online resources

The Intervention Programme targeted three cohorts of students in particular (Group A, Group B and Group C) who had previously been identified as 'low achievers'. For more detail on why these groups were selected to participate in the Intervention Programme, refer to section 3.3. All three phases of the Intervention Programme were optional for the students; attendance was voluntary, and they did not receive any extra course credits for taking the programme. The Intervention Programme was advertised by the students' course lecturer and through e-mail. Available slots on the students' timetables were selected and a weekly tutorial, which lasted fifty minutes, was organised for each group. The students were kept in their course groups and each group was taken at different times for their tutorial sessions. It was decided to take this approach, as the different groups had different needs, and as a whole, were at different levels in their Chemistry knowledge.

At the first tutorial session, each group of students completed a pre-diagnostic test including an attitude and confidence test, and background information was also collected. Based on the results of the pre-test, a tailored Intervention Programme was designed for each group, although they all had common features. This was an important premise behind the Intervention Programme as the main aim was to address and meet the students' needs, rather than approach them with preconceived ideas of what they found difficult, or what was thought to be lacking in their understanding (Berg, 2005). Even though all the students showed similar misconceptions based on the results of the diagnostic testing, the tutorials were designed to cater specifically to each group's difficulties and moved at different paces. In the last tutorial session, students completed a post-diagnostic test as well as a post-attitude and confidence test. A variety of teaching and learning techniques were used within the tutorials, including blended learning, inquiry-based learning, use of formative assessment and a constructivist approach when appropriate (Coll and Taylor, 2001).

At the end of Phase 2, interviews were carried out with six participating students. This allowed the opportunity to get an insight into the areas of Chemistry students found particularly difficult, as well as their thoughts and opinions on the Intervention Programme.

3.2.1 Phase 1 of the Intervention Programme

Phase 1 of the Intervention Programme took place in the students' second year, in the first academic semester of 2009-2010. This phase was carried out in the same style as the pilot study (Hayes & Childs, 2010). The only difference was that the Intervention Programme was made available to three groups of 'at risk' students rather than just two groups in the pilot study. Participating students completed a pre-diagnostic test based on basic chemical concepts and ideas, as well as an attitude and confidence test. Information was also gathered on the students' academic backgrounds. The diagnostic test tested students' knowledge on basic Chemistry topics and the results of the pre-test determined the detailed content of the tutorials. Phase 1 consisted of consisted of 10 weeks of tutorials, which concentrated on basic Chemistry ideas and concepts. Weeks 1 and 10 were taken up with the diagnostic tests. Table 3.2 shows the structure of the weekly tutorials and the topics that were covered with the students. However, a major limitation of Phase 1 was that no students attended the last tutorial session to complete the post-diagnostic test. This meant that it was impossible to evaluate if the Intervention Programme had improved their score in the post-diagnostic test. The last tutorial session was one week before the start of students' examinations and this may have been a contributing factor to the lack of attendance. It was, however, possible with this group to assess their prior knowledge, misconceptions, attitudes and confidence from the pre-diagnostic test.

Table 3.2 Breakdown of tutorial weeks and topics covered. (In Phase 1, Phase 2-Part 1 and Phase 3)

Tutorial Week	Chemistry Topic
1	Tests administered
2	Structure of the Atom
3	How to use the periodic table, Electronic Configuration
4	Naming Compounds
5	Balancing Equations
6	Chemical Bonding
7	Chemical Bonding
8	Oxidation and Reduction
9	Question and Answer Session
10	Tests administered

3.2.2 Phase 2 of the Intervention Programme

Phase 2 of the project consisted of two parts. Due to the unsuccessful post-diagnostic testing of the groups in Phase 1 due to poor attendance, it was decided to design Phase 2 of the project with some modification. It was decided to target the students earlier in their courses of study and also extend the duration of the Intervention Programme to two semesters. The Phase 2 Intervention Programme was made available to the same groups of students during these two semesters. The first semester (Part 1) focused on basic Chemistry ideas and concepts and the second semester (Part 2) moved on to dealing with chemical calculations and the mole. By doing this, participating students got an opportunity to address both areas of difficulty, but in more depth than in Phase 1.

Part 1 of the Intervention Programme took place in the students' first year, in the second academic semester of 2009-2010, following a 'General Chemistry' module in the first semester. Similar to Phase 1, participating students completed a pre- and post-diagnostic test including an attitude and confidence test. Part 1 consisted of 10 weeks of tutorials, which concentrated on basic Chemistry ideas and concepts that were shown to be an issue by the pre-diagnostic tests. Table 3.2 shows the structure of the weekly tutorials and the topics that were covered with the students, which was the same as in Phase 1. Online resources were also made available to students as well as worksheets.

Part 2 of the Intervention Programme took place in the students' second year, in the first academic semester of 2010-2011. It was a continuation of Part 1 and involved the same groups of students. During Part 2, Group A and Group B were studying an 'Inorganic Chemistry' module and Group C were studying an 'Analytical Chemistry' module. This phase consisted of nine weeks of tutorials focusing on chemical calculations, and in particular, the mole concept. Similar to Phase 1, participating students completed a pre- and post-diagnostic test including an attitude and confidence test. However, a different diagnostic test was used in Part 2 from that in Part 1. This diagnostic test tested students' ability to carry out chemical calculations. Similarly, based on the students' results in the pre-diagnostic tests, the detailed content of the Intervention Programme was developed. Table 3.3 shows the structure of the weekly tutorials and the topics that were covered with the students in Part 2. Online resources were also made available to students as well as worksheets.

Table 3.3 Breakdown of tutorial weeks and topics covered for Phase 2, Part 2.

Tutorial Week	Chemistry Topic
1	Tests administered
2	The Mole
3	Using Avogadro's Number
4	Stoichiometry 1
5	Stoichiometry 2
6	Concentration and Molarity
7	Volumetric Analysis
8	Question and Answer Session
9	Tests administered

3.2.3 Phase 3 of the Intervention Programme

Phase 3 of the Intervention Programme took place in the students' first year, in the second academic semester of 2010-2011, and involved a new cycle of students. It involved the same diagnostic test and attitude and confidence test that was used in Phase 1 and Phase 2, Part 1. It was planned to follow these students again in their second year of study as was the case in Phase 2, however, due to lack of time this was not feasible. Phase 3 consisted of 10 weeks of tutorials, which concentrated on basic Chemistry ideas and concepts that were shown to be an issue by the pre-diagnostic tests. Table 3.2 shows the structure of the weekly tutorials and the topics that were covered with the students.

3.3 Research Subjects

For all three Phases, the same three cohorts of students were used in the Intervention Programme. These groups were selected due to a number of reasons. Each group had been identified as low achievers in Chemistry due to the following reasons:

- Little or no Chemistry studied at second level
- Academic background is weak (as measured by CAO points)
- An increase in the number of non-standard students
- In previous years, students in these course groups have performed poorly in third level Chemistry examinations
- High level of attrition in Chemistry courses by these course groups in the past.

This section will give relevant information about the participating students and also the courses they were studying.

The programme was offered to everyone in the three target groups, without distinguishing between weaker and stronger students.

3.3.1 Numbers of Participating Students

Table 3.4 shows the breakdown of numbers of each group who took part in the Intervention Programme. Only students who completed both the pre-diagnostic test and the post-diagnostic test could be assessed for their overall performance. For example in Phase 2 (Part 2), 23 students from Group A completed the pre-diagnostic test on the first tutorial session. On the last tutorial session 11 students from Group A completed the post-diagnostic test. However, only 5 of the students had completed both the pre- and post-diagnostic tests so therefore only 5 students' progress could be assessed. However, the pre-diagnostic tests for all Phases and groups could be used to assess and compare the level of preparedness of these students and the areas of Chemistry they have difficulty with. This, in itself, is useful information in describing the students' capability for studying Chemistry.

Table 3.4 Breakdown of Participating Students in Intervention Programme.

	No. of students tutorials were offered to	No. of students who completed pre-test	No. of students who completed post-test	No. of students who completed both pre- and post-test
Phase 1 (2^{nd} year, Semester 1)				
Group A	44	7	0	0
Group B	25	5	0	0
Group C	26	4	0	0
Total	*95*	*16*	*0*	*0*
Phase 2 - Part 1 (1^{st} year Semester 2)				
Group A	47	23	11	5
Group B	20	16	11	7
Group C	32	16	13	8
Total	*99*	*55*	*35*	*20*
Phase 2 - Part 2 (2^{nd} year, Semester 1)				
Group A	47	10	6	3
Group B	24	12	5	4
Group C	29	15	6	2
Total	*100*	*37*	*17*	*9*
Phase 3 (1^{st} year, Semester 2)				
Group A	27	14	13	7
Group B	26	5	5	5
Group C	44	16	8	6
Total	*97*	*35*	*26*	*18*

3.3.2 Course Information of Participating Students

Table 3.10 outlines information on each of the three courses that the target groups were studying at the time of the Intervention Programme. The table includes information on the duration of the course, the CAO points needed to enter that course, the Science subject entry requirements, Mathematics entry requirements and the Chemistry and Mathematics modules studied by students over the duration of the course. It is important to note that in order to study any of the courses, only one Science subject is required at either higher or ordinary level for the Leaving Certificate Examination. Thus, although the courses include significant Chemistry content, many students meet Chemistry essentially for the first time at University.

Table 3.5 Course Information and Entry Requirements.

	Group A	Group B	Group C
Course Title	Bachelor of Science in Environmental Science	Bachelor of Science in Health & Safety	Bachelor of Science in Food Science and Health
Course Duration	4 Years	4 Years	4 Years
Minimum CAO Entry Points 2010	360	345	360
Science Entry Requirements	Any **one** subject from the following (Higher or Ordinary level): • Agricultural Science • Biology • Chemistry • Physics • Physics & Chemistry	Any **one** subject from the following (Higher or Ordinary level): • Agricultural Science • Biology • Chemistry • Physics • Physics & Chemistry	Any **one** subject from the following (Higher or Ordinary level): • Agricultural Science • Biology • Chemistry • Physics • Physics & Chemistry
Mathematics Entry Requirements	Mathematics (Higher or Ordinary level) *	Mathematics (Higher or Ordinary level)*	Mathematics (Higher or Ordinary level)*
Chemistry modules throughout course	• General Chemistry (year 1) • Physical Chemistry (year 1) • Inorganic Chemistry (year 2) • Analytical Chemistry (year 2) • Environmental Chemistry (year 2) • Organic Chemistry (year 2)	• General Chemistry (year 1) • Biochemistry (year 2) • Inorganic Chemistry (year 2) • Analytical Chemistry (year 2) • Organic Chemistry (year 2)	• General Chemistry (year 1) • Biochemistry (year 2) • Analytical Chemistry (year 2, 3) • Organic Chemistry (year 1, 2) • Food Chemistry (year 2, 4)
Mathematics modules throughout course	• Science Mathematics (Year 1)	• Science Mathematics (Year 1)	Science Mathematics (Year 1, 2)

* Applicants are required to hold at least the following in the Leaving Certificate or an approved equivalent: Grade C3 in Higher level Mathematics and a grade D3 in a Higher or Ordinary level paper in any one of the following: Physics, Chemistry, Physics with Chemistry, Engineering, Technical Drawing/Design & Communication Graphics, Technology, Agricultural Science, Biology OR Grade B3 in Ordinary level Mathematics (Grade D3 in Higher level Mathematics also suffices) and grade C3 in one of the following Higher level papers Applied Mathematics, Physics, Chemistry, Physics with Chemistry, Biology, Agricultural Science (University of Limerick Prospectus, 2012).

3.4 Design of Testing Instrument

The testing instrument used for all three phases of this study consisted of a diagnostic test, which also included an attitude and confidence test. However, a different instrument was used for Part 2 of Phase 2. Testing took place during the first and last tutorial session of each phase. Information on students' academic background was also collected during the first tutorial session of each phase.

3.4.1 Background Information

On the first tutorial session of each Phase, students were asked to fill out information sheets, which contained questions about their academic background. The questions asked whether the students had previously studied Chemistry for their Leaving Certificate Examination, and if so what level paper did they take and what grade they achieved. Also, students were asked about their background in Mathematics and whether they had studied it for their Leaving Certificate Examination, and if so at what level and what grade they achieved.

3.4.2 Diagnostic Tests

The value and benefit of diagnostic testing has already been discussed in section 2.5.3. The results of the pre-diagnostic test provided a clear picture of the areas that students were particularly struggling with and helped design the content of the tutorials. The same pre- and post-diagnostic tests were used in Phase 1, Phase 2 (Part 1) and Phase 3 of the study. The pre-test focused on basic Chemistry topics and included questions like balancing a chemical equation and writing formulae. The post-diagnostic test was almost identical to the pre-test; some questions were repeated and some questions were the same style but with different figures used. The diagnostic test was based on core Chemistry concepts and ideas and contained a total of 16 questions, some of them multiple choice and some free response. Some questions used words only and some involved illustrations. The full pre- and post-diagnostic tests of Phase 1, Phase 2-Part 1 and Phase 3 can be seen in the Appendix section. Figure 3.2and Figure 3.3 are examples of two of the questions that appeared on both the pre- and post-diagnostic tests.

Q3. The identity of an element is determined by the number of which particle?

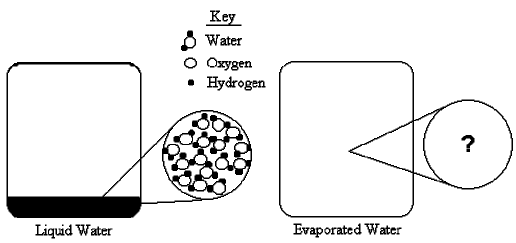
Protons ___

Neutrons ___

Electrons ____

Figure 3.2 Question 3 used on both the Pre- and Post-Diagnostic Test.

Q16. The circle on the left shows a magnified view of a very small portion of liquid water in a closed container.



What would the magnified view show after the water evaporates?

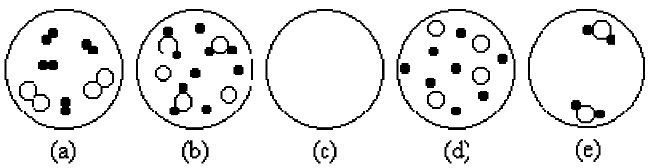


Figure 3.3 Question 16 used on both the Pre- and Post-Diagnostic Test.

Some off the questions in the test instrument were taken from various validated chemical concept inventories and General Chemistry texts (see Table 3.11) while some were developed by the author. Questions were designed to ascertain the students' knowledge and in some questions to identify the students' misconceptions. The free response questions were included to enable us to investigate students' thinking behind the response to questions, and to examine their approach to the question. One point was awarded for each correct answer, so that a total of 16 points could be achieved. This allowed testing of the concepts that are key to an understanding of basic General Chemistry topics, which would be covered in

Leaving Certificate Chemistry and in a first year General Chemistry module. All of the students would have done the first year General Chemistry module even if they had not studied Chemistry at school.

Table 3.11 Areas tested on Pre- and Post-Diagnostic Test (Used in Phase 1, Phase 2 part 1 and Phase 3)

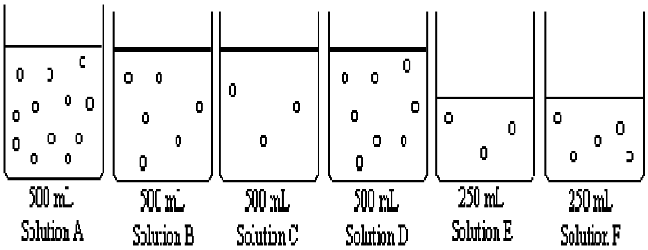
Concept Area	Questions	Sources of Questions
Particulate Nature of Matter	5,7,14, 15,16	Mulford and Robinson (2002); Sheehan (2010) *Chemistry Live*
Atomic structure	1,2,3,6,	Developed by Author
Chemical reactions	4	Mulford and Robinson (2002); Sheehan (2010); Developed by the author
Chemical Formulas	8,11	Developed by the author
Oxidation and Reduction	9	*Chemistry Live!*
Chemical Bonding	10	*Chemistry Live!*
Reacting masses and Stoichiometry	12,13	Developed by the author

For Phase 2, Part 2, a different diagnostic test was used. As this phase focused on chemical calculations, and in particular the mole, this test was mostly composed of calculation-based questions which examined students' ability to correctly complete both easier calculations and more challenging ones. The diagnostic test contained 11 questions, some of which contained several parts. The full pre- and post-diagnostic tests of Phase 2-Part 2 can be seen in the Appendix section. Figure 3.4 and Figure 3.5 are examples of two of the questions that appeared on both the pre- and post-diagnostic tests. Some questions involved words only and some involved visual material.

3) How many moles of acetic acid (CH_3CO_2H) are there in a 10.0g sample?

Figure 3.4 Question 3 used on both the Pre- and Post-Diagnostic Test.

6) The drawings below represent beakers of aqueous solutions.



Answer the following questions.

Put A, B, C, D, E or F in the spaces provided:

a) Which solution is most concentrated? Solution ____

b) Which solution is least concentrated? Solution ____

c) Which two solutions have the same concentration? Solution ____ and _____

d) When Solutions E and F are combined, the resulting solution has the same concentration as Solution ___

e) If you evaporate off half of the water in Solution B, the resulting solution has the same concentration as Solution _____.

Figure 3.5 Question 6 used on both the Pre- and Post-Diagnostic Test.

Table 3.12 shows the sources of the questions used and the area they were used to test. One point was given for each correct answer and in total 22 points could be achieved. Again the post-test was very similar to the pre-test with some questions being repeated and some having different figures.

Table 3.12 Areas tested on Pre- and Post-Diagnostic Test (Used in Phase 2)

Concept Area	Questions	Sources of Questions
The Mole	1,2,3,4	Developed by Author
Using Avogadro's Number	5	Developed by Author
Stoichiometry	7,8,9,10,11	*Chemistry Live!*
Concentration	6	Sheehan (2010)

3.4.3 Attitude and Confidence Test

On the first and also the last tutorial session of all phases, students were asked to complete an attitude and confidence test which was based on a published instrument 'Field-tested learning assessment guide' (Moore and

Kosciuk, 1999). These tests had a six point Likert scale, with 1 being 'very low' confidence level to being 'very high' confidence level. There was a N/A option which stood for Not Applicable (No Opinion). Students circled the number corresponding to each question which best suited their response. Figure 3.6 shows a sample of the statements that students had to evaluate. The same test was used before and after the Intervention programme so that students' confidence levels and attitudes towards Chemistry could be assessed before and after the Intervention Programme.

		confidence level					
	CONFIDENCE IN YOUR ABILITY TO...	n/a	Very low	Low	Average	High	Very high
1)	Understand key concepts of chemistry and explain topics in own words	0	1	2	3	4	5
2)	Choosing an appropriate formula to solve a chemistry problem	0	1	2	3	4	5
3)	Approach a chemistry problem in a systematic manner, working step by step	0	1	3	3	4	5
4)	Determine the appropriate units for a result determined using a formula	0	1	2	3	4	5
5)	Read the procedures for an experiment and conduct the experiment without supervision	0	1	2	3	4	5

Figure 3.6 Statements from Confidence and Attitude Test (**based on *Moore and Kosciuk, 1999).**

3.5 Design of Tutorials

The tutorials ran for nine to ten weeks in each phase and consisted of a variety of topics. Each tutorial lasted 50 minutes and took place each week. All groups were taken seperately and had one designated slot. Only students that filled out both a pre- and post-diagnostic test could be evaluated on their overall performance. However, during the course of the Intervention Programme, many other students attended but were not present on the first or last session for testing so their progress could not be monitored. Students who attended six or more tutorials and completed both the pre- and post-diagnostic test were regarded as ‘participating students’. Due to the voluntary nature of the tutorials, the attendance was poor and inconsistent. Not all the students to whom the programme was offered decided to participate and those that did participate did not attend every week. This also meant that not all of the ‘at risk’ students attended, and the inconsistent attendance affected the number of students whose progress could be validly monitored.

3.5.1 Blended Learning

Blended learning is the combination of multiple approaches to learning and can be effective. Blended learning involves face to face contact with students in the form of weekly tutorials as well as a web-based element of teaching and learning. There are many benefits to this approach. It gives both the students and facilitator flexibility. Online resources were made available for students who participated in the Intervention Programme. Online quizzes, helpful websites, animations and question and answer forums were available for students. The online content could be viewed anywhere at anytime and questions, quizzes, etc. can be answered in students’ own time giving them the opportunity to put more thought into their answers. Due to the instant feedback feature, students were able to monitor their own degree of personal involvement in the tutorials. ICT records showed students activity on the webpage and indicated number of users, grades, time it took to complete exercises, etc. Any Powerpoint presentations used throughout the Intervention Programme were also made available to students.

Worksheets were provided to the students each week also which they worked on during the tutorials. They included questions for students on different chemical concepts. Exercises which they could complete on their own and also some exercises that they were asked to work in pairs were included. However, if students did not attend the tutorial on a particular week, they then missed out on the worksheet for that tutorial session.

The literature on the potential of communication technology to support meaningful educational experiences has been well documented. For example, it has been shown that online collaboration supports flexibility and collaborative learning environments resulting in deep and meaningful learning

(Garrison & Anderson, 2003). By providing online information and instant, tailored feedback on quizzes, students have an opportunity to assess their own work. It was hoped to introduce an interactive response system in the form of clickers into Phase 2 and Phase 3. However, due to many problems encountered with the software this was not feasible.

3.5.2 Approaches to Teaching and Learning used in Tutorials

There was a variety of teaching and learning approaches used during the tutorials. Due to the smaller number of students that attended in each group, it was easier to carry out different approaches as there was a friendly atmosphere, where everyone worked and helped each other. This created a very student-centred approach to the tutorials. Perkins's (2007) model of teaching 'smarter' not 'harder' was invoked when designing the Intervention Programme. Given that there are *'flaws in the standard approach'* (Herron 1999, p. 3) and in order for the effects of the intervention to be sustainable, it was necessary to assess not only the students' prior knowledge, but also their conceptual understanding of some basic areas of general Chemistry, and to uncover their chemical misconceptions. These areas underpin introductory courses in Chemistry. One of the most beneficial approaches used during the tutorials was the use of formative assessment. Testing students each week on what was covered the previous week, using coloured cards to assess whether students were comfortable with a topic and were ready to move on all worked well. This type of assessment was something the students mentioned during the interviews as something they would like to have more of in a lecture setting, as it ensures no one is left behind. Figure 3.7 shows the main components of the Intervention Programme.

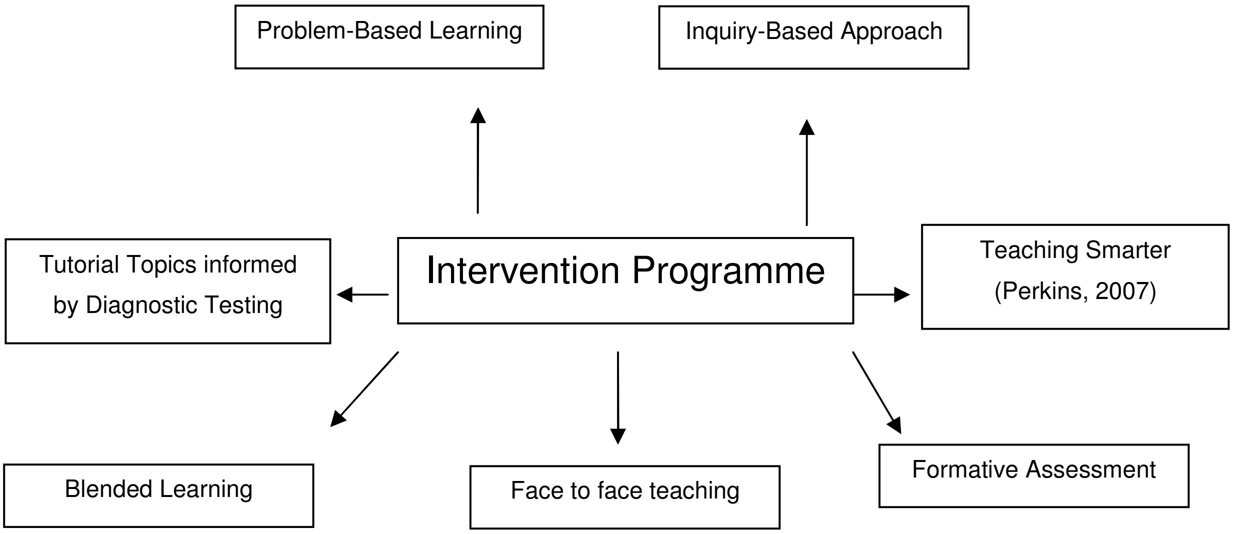


Figure 3.7 Components of the Intervention Programme.

3.6 Interviews

As Part 1 and Part 2 of Phase 2 tracked the same group of students from the second academic semester of their first year of study to the first academic semester of their second year of study, it was decided to carry out interviews with some of the students as they had experience of both phases: Phase 1 (Basic Chemistry ideas and concepts) and Phase 2 (Chemical calculations and the mole). At the end of Phase 2 interviews were carried out with six students. All of the students selected had completed both the pre- and post-diagnostic test. Two students were selected from each group (Group A, Group B and Group C): one achieving a high score in the diagnostic test and one achieving a low score on the test. The interviews were semi-structured with a pre-prepared list of questions, which can be seen in the Appendix section. A semi-structured interview was decided upon as it allowed for the interviewer to further probe the students' responses. There was also opportunity for development of the students' answers to the tests. With the students' permission, all interviews were recorded and transcribed. It was decided to conduct interviews with high performing and low performing students (in diagnostic test) after completion of the Intervention Programme as it was thought that it was more appropriate at this time. It was hoped to carry out interviews with more students, however, due to time constraints (as it was approaching examination time for the students), it was difficult to get the students to commit time to the interviews. The findings of the interviews will be discussed in the results chapter.

3.7 Modifications of Intervention Programme from Pilot Study

As mentioned earlier, the Intervention Programme discussed here was a follow on from work done by Hayes and Childs 2010 on the development of an Intervention programme for a second year group of students in the University of Limerick. Taking into account some of the limitations of this pilot study, a number of modifications were made to the expanded Intervention Programme. It was decided to make the expanded Intervention Programme longer in duration and run it over 2 semesters instead of 1. This provided the opportunity to tackle another area of Chemistry which students found difficult. As well as that, the Intervention Programme began earlier in the students' first year of study. Findings from the pilot study and also Phase 1, showed that the students' prior chemical knowledge was quite poor, and that the earlier the students were targeted the better. The original pilot Intervention Programme was developed for two groups of students (Group A and Group B), but for the expanded Intervention Programme a third group were introduced, Group C. This group of students was also known to be made up of 'low achievers'. Phase 2 and Phase 3 also adopted a blended learning approach, allowing students to access online resources as well as the use of worksheets during the weekly tutorial sessions. Figure 3.8 outlines the differences between the original pilot study and the expanded Intervention Programme.

Pilot Study

- **9 Week Programme.**
- **Offered to 2 groups of students.**
- **Semester 1, Year 2 of their study.**
- **1 semester duration.**

Expanded Study

- **9/10 Week Programme.**
- **Offered to 3 groups of students.**
- **2 semester duration.**
- **Online resources and worksheets available**

Figure 3.8 Diagram summarising differences between Pilot study and expanded Intervention Programme.

3.8 Data Analysis

The data collected from the investigation was analysed using the statistical software package SPSS (Statistical Package for the Social Sciences version 16.0 for Windows) and PASW (Predictive Analytics Software version 17.0 for Windows). PASW is the upgraded, renamed SPSS; files which were originally in SPSS were transferred in their entirety from one software package to the other. The analysis procedure was the same for all tests. All questions were coded, as were the responses, and entered into SPSS or PASW using these codes. Any missing data was also coded, so as to ensure that no question was answered with a significantly lower frequency than other questions. When all data had been entered into the software package, initial frequency checks were carried out to detect coding errors in the data.

This first level analysis involved graphical representations such as bar charts. Whether or not data was considered to be parametric was considered from the first level analysis and depending on the type of data, independent sample t-tests and paired sample t-tests were used. The findings of this data analysis are discussed in detail in the results chapter. Given the nature of some of the data collected, and the lack of validity of the sample due to low attendance, there was no need for further analysis, beyond the descriptive level. The data collected was represented in both graphical and tabulated mode. The qualitative responses were analysed manually. Themes were identified and analysed. The variety of the responses meant that input into a statistical package was not valid due to the low number of interviews conducted.

Chapter Four

Results & Analysis

4.1 Introduction

This chapter will give an overview of the results obtained from all three phases. Phase 1 involved 3 groups of second year students, Phase 2 was made up of 2 parts and involved 3 groups of first year students (Part 1) and second year students (Part 2). During Phase 2, the same cohort of students were involved in both parts, beginning in their first year of study and continuing into their second year. Phase 3 included 3 groups of first year students. Students' academic backgrounds will be looked at as well as performance in pre- and post-diagnostic tests, performance of students in their concurrent Chemistry modules, students' attitudes and confidence towards Chemistry and the usage of online resources that were made available to students during the Intervention Programme. At the end of Phase 2, student interviews were carried out, the findings of which will also be discussed in this chapter.

4.2. Student Background

During the testing period, students were also asked to fill out a background information sheet, which asked students to give detail about their academic background in relation to Chemistry and Mathematics. The following tables (4.1, 4.2, 4.3, 4.4) outline this information for all three groups for Phase 1, Phase 2 and Phase 3. Standard and non-standard students are referred to in the following tables. Standard students refer to the traditional intake of students who complete the Leaving Certificate Examination and based on the CAO points they achieve, receive a place on their chosen course of study. Non-standard students refer to mature students over the age of 23 who return to University. These non-standard students range from people who have previously completed a undergraduate course and have decided to complete another course of study in a related/non-related area and people who have been in the workforce for a number of years and due to the current economic climate, have been forced to return to third level education to re-train in a different area to improve their job prospects. Many non-standard students have not studied Chemistry for quite a while and others have no experience of studying Chemistry. As well as this, the majority of non-standard students have limited or no experience of studying Mathematics.

Table 4.1 Academic Background of Participating Students from Groups A, B and C of Phase 1

Phase 1			
	Group A	**Group B**	**Group C**
No. of students who completed pre-test	7	5	4
Gender	4 (57%) Female 3 (43%) Male	3 (60%) Female 2 (40%) Male	1 (15%) Female 3 (75%) Male
Standard (S)/ Non-Standard (N/S) Student	5 (71%) S 2 (39%) N/S	4 (80%) S 1 (20%) N/S	4 (100%) S
Chemistry at L.C.	3 (43%) Yes 4 (57%) No	2 (40%) Yes 3 (60%) No	4 (100%)No
Level of Chemistry Exam	3 (100%) Ordinary	2 (100%) Ordinary Level	-
Mathematics at L.C.	7 (100%) Yes	4 (80%) Yes 1 (20%) No	4 (100%) Yes
Level of Mathematics Exam	4 (57%) Ordinary 3 (43%) Higher	3 (75%) Ordinary 1 (25%) Higher	2 (50%) Ordinary 2 (50%) Higher

Table 4.2 Academic Background of Participating Students from Groups A, B and C of Part 1 of Phase 2.

Phase 2 (Part 1)			
	Group A	**Group B**	**Group C**
No. of students who completed both pre- and post-test	5	7	8
Gender	3 (60%) Female 2 (40%) Male	4 (57%) Female 3 (43%) Male	3 (38%) Female 5 (62%) Male
Standard (S)/ Non-Standard (N/S) Student	2 (40%) S 3 (60%) N/S	2 (29%) S 5 (71%) N/S	3 (38%) S 5 (62%) N/S
Chemistry at L.C.	3 (60%) Yes 2 (40%) No	1 (14%) Yes 6 (86%) No	2 (25%) Yes 6 (75%) No
Level of Chemistry Exam	3 (100%) Ordinary	1 (100%) Ordinary Level	1 (50%) Ordinary 1 (50%) Higher
Mathematics at L.C.	4 (80%) Yes 1 (20%) No	4 (57%) Yes 3 (43%) No	5 (62%) Yes 3 (38%) No
Level of Mathematics Exam	2 (50%) Ordinary 2 (50%) Higher	1 (25%) Ordinary 3 (75%) Higher	3 (60%) Ordinary 2 (40%) Higher

Table 4.3 Academic Background of Participating Students from Groups A, B and C of Part 2 of Phase 2.

Phase 2 (Part 2)			
	Group A	**Group B**	**Group C**
No. of students who completed both pre- and post-test	3	4	2
Gender	3 (100%) Female		2 (100%) Male
Standard (S)/ Non-Standard (N/S) Student	2 (67%) S 1 (33%) N/S	1 (25%) S 3 (75%) N/S	2 (100%) N/S
Chemistry at L.C.	2 (67%) Yes 1 (33%) No	2 (50%) Yes 2 (50%) No	1 (50%) Yes 1 (50%) No
Level of Chemistry Exam	2 (100%) Ordinary	1 (50%) Ordinary 1 (50%) Higher	1 (100%) Ordinary
Mathematics at L.C.	2 (67%) Yes 1 (33%) No	1 (15%) Yes 3 (75%) No	2 (100%) No
Level of Mathematics Exam	2 (100%) Ordinary	1 (100%) Higher	0%

Table 4.4 Academic Background of Participating Students from Groups A, B and C of Phase 3.

Phase 3			
	Group A	**Group B**	**Group C**
No. of students who completed both pre- and post-test	7	5	6
Gender	4 (57%) Female 3 (43%) Male	2 (40%) Female 3 (60%) Male	3 (50%) Female 3 (50%) Male
Standard (S)/ Non-Standard (N/S) Student	4 (57%) S 3 (43%) N/S	3 (60%) S 2(40%) N/S	5 (83%) S 1 (17%) N/S
Chemistry at L.C.	4 (57%) Yes 3 (43%) No	2 (40%) Yes 3 (60%) No	4 (67%) Yes 2 (33%) No
Level of Chemistry Exam	3 (75%) Ordinary 1 (25%) Higher	2 (100%) Ordinary	2 (50%) Ordinary 2 (50%) Higher
Mathematics at L.C.	5 (71%) Yes 2 (29%) No	3 (60%) Yes 2 (40%) No	5 (83%) Yes 1 (17%) No
Level of Mathematics Exam	3 (60%) Ordinary 2 (40%) Higher	3 (100%) Ordinary	3 (60%) Ordinary 2 (40%) Higher

It is important to note from the information obtained, that the students who had not studied Mathematics for the Leaving Certificate Examination were all non-Standard students and had not completed a Leaving Certificate

Examination or equivalent. However, they all had experience of doing Mathematics to some level during their schooling.

Table 4.5 shows a summary of the percentage of students who had studied Chemistry and Mathematics for the Leaving Certificate Examination and the level of the paper they completed for all three phases.

Table 4.5 Summary of students who completed Chemistry and Mathematics at Leaving Certificate Level.

	Phase 1	Phase 2, Part 1	Phase 2, Part 2	Phase 3
% who have studied Chemistry (L.C.)	31%	30%	56%	56%
% who took a Chemistry higher level paper	0	17%	20%	30%
% who took a Chemistry ordinary level paper	100%	83%	80%	70%
% who have studied Mathematics (L.C.)	94%	65%	33%	72%
% who took a Mathematics higher level paper	40%	54%	33%	31%
% who took a Mathematics ordinary level paper	60%	46%	67%	69%

4.2.1 Phase 1 (Year 2, Semester 1, 2009)

Phase 1 concentrated on teaching students about basic Chemistry concepts and ideas. 16 students completed a pre-diagnostic test, however, as already discussed, none of the students attended the last tutorial of the Intervention Programme to complete the post-diagnostic test. The last tutorial coincided with the University of Limerick's study week prior to the beginning of examinations, so it is thought that this played a role in the lack of student attendance. The results of the pre-diagnostic tests completed by the students will be looked at, but it is not possible to compare the students' performance between the pre-test and the post-test, as will be done in the other phases. However, completion of the pre-tests alone have provided a valuable insight into the preparedness of students studying Chemistry at third level and this will be discussed. Also, changes in attitude and confidence levels towards Chemistry could not be assessed as only a pre-attitude and confidence test was completed. Of the 16 participating students, 8 (50%) were male and 8 (50%) were female. 13 (81%) were standard students and 3 (19%) were non-standard students. Figure 4.1 shows that in Group A, 3 (43%) of the students had studied Chemistry for their Leaving Certificate Examination, 2 (40%) in Group B and none of the students in Group C had taken Leaving Certificate Chemistry. 7 (100%) of Group A had studied Mathematics for their Leaving Certificate Examination, 4 (80%) in Group B and 4 (100%) in Group C. See Section 3.3.2 for more detail on the levels of subjects taken by the students.

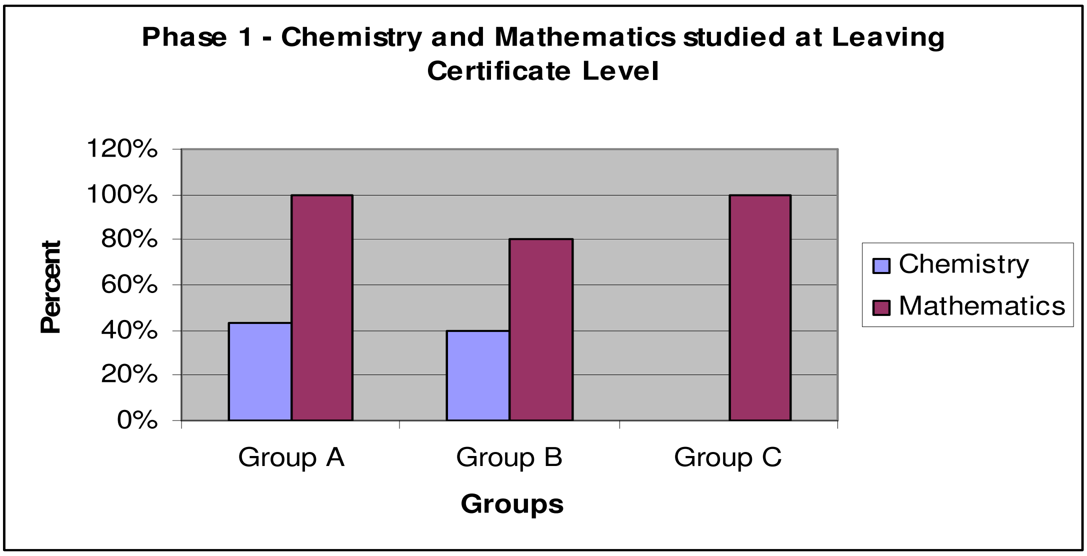


Figure 4.1 Phase 1 - Chemistry and Mathematics studied at Leaving Certificate Level.

4.2.2 Phase 2

Phase 2 involved two parts, Part 1 and Part 2. Results from each part will be discussed separately.

4.2.2.1 Part 1 (Year 1, Semester 2, 2010)

Part 1 focused on teaching students basic Chemistry concepts and ideas (similar to Phase 1). There were 20 students in Part 1 that could be assessed as they had completed both the pre- and post-diagnostic test. 10 (50%) were male and 10 (50%) were female. 7 (35%) were standard students and 13 (65%) were non-standard students. Figure 4.2 shows that in Group A, 3 (60%) of the students had studied Chemistry for their Leaving Certificate Examination, 1 (14%) in Group B and 2 (25%) for Group C. 4 (80%) of Group A had studied Mathematics for their Leaving Certificate Examination, 4 (57%) in Group B and 5 (62%) in Group C. See Section 3.3.2 for more detail on the levels of subjects taken by the students.

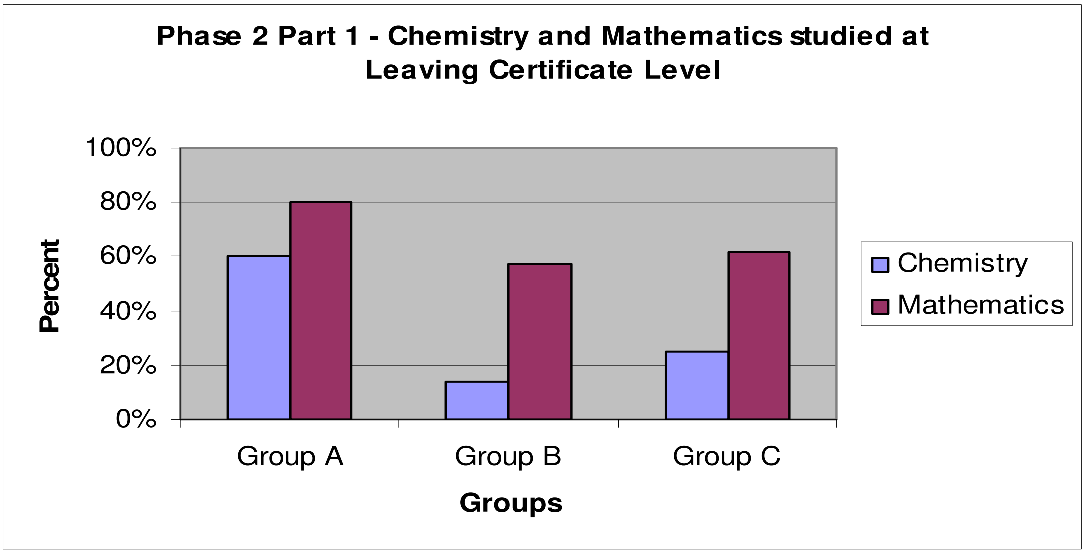


Figure 4.2 Phase 2 Part 1 - Chemistry and Mathematics studied at Leaving Certificate Level.

4.2.2.2 Part 2 (Year 2, Semester 1, 2010)

Part 2 concentrated on teaching students how to carry out chemical calculations and in particular the mole concept. There were 9 students in Part 2 that could be assessed as they had completed both the pre- and post-diagnostic test. 5 (56%) were male and 4 (44%) were female. 3 (33%) were standard students and 6 (67%) were non-standard students. Figure 4.3 shows that in Group A, 2 (67%) of the students had studied Chemistry for their Leaving Certificate Examination, 2 (50%) in Group B and 1 (50%) for Group C. 2 (67%) students in Group A had studied Mathematics for their Leaving Certificate Examination, 1 (15%) in Group B and no-one in Group C had studied it. See Section 3.3.2 for more detail on the levels of subjects taken by the students.

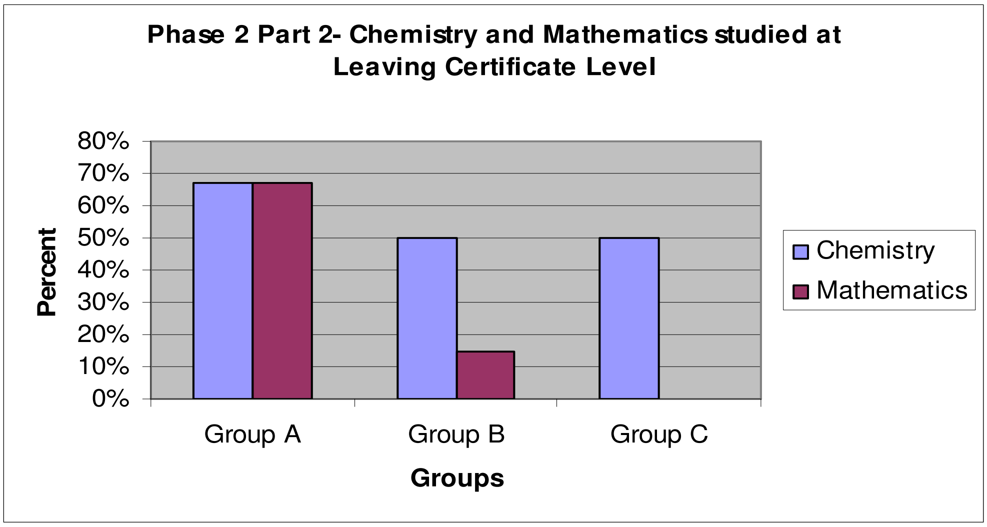


Figure 4.3 Phase 2 Part 2 - Chemistry and Mathematics studied at Leaving Certificate Level.

4.2.3 Phase 3 (Year 1, Semester 2, 2011)

Phase 3 focused on teaching students about basic Chemistry concepts and ideas. There were 18 students in Phase 3 that could be assessed as they had completed both the pre- and post-diagnostic test. 9 (50%) were male and 9 (50%) were female. 12 (67%) were standard students and 6 (33%) were non-standard students. Figure 4.4 shows that in Group A, 4 (57%) of the students had studied Chemistry for their Leaving Certificate Examination, 2 (40 %) in Group B and 4 (67%) for Group C. 5 (71%) students in Group A had studied Mathematics for their Leaving Certificate Examination, 3 (60%) in Group B and 5 (83%) in Group C. See section 3.3.2 for more detail on the levels of subjects taken by the students.

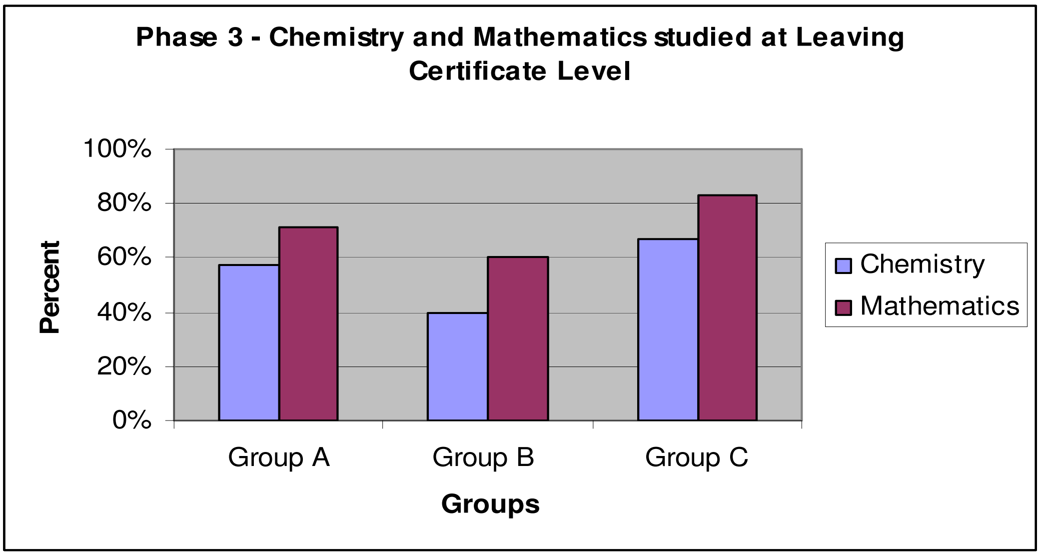


Figure 4.4 Phase 3 - Chemistry and Mathematics studied at Leaving Certificate Level.

4.3 Preparedness of Students

The performance of students in the diagnostic test could only be measured for students who completed both the pre- and post-diagnostic tests. A large number of students during the three phases completed a pre-diagnostic test and may or may not have attended the last tutorial session to take part in the post-testing. However, the results of the pre-tests show two important findings. Firstly, students perform poorly in the pre-diagnostic tests whether they have experience of leaving Certificate Chemistry or not. The average mark that students achieved in the pre-test was 38%. The second finding that emerged from these results was that many of the students were showing similar misconceptions, getting the same questions incorrect and also choosing the same incorrect option for conceptual questions. This highlights that many students entering third level are not prepared for the demands of studying Chemistry. Figure 4.5 shows the results of question 16 on the pre-diagnostic test. All students scored poorly in this question and also the majority of students believed that option D was the correct answer implying that they believed when water evaporates, hydrogen and oxygen atoms split into individual atoms.

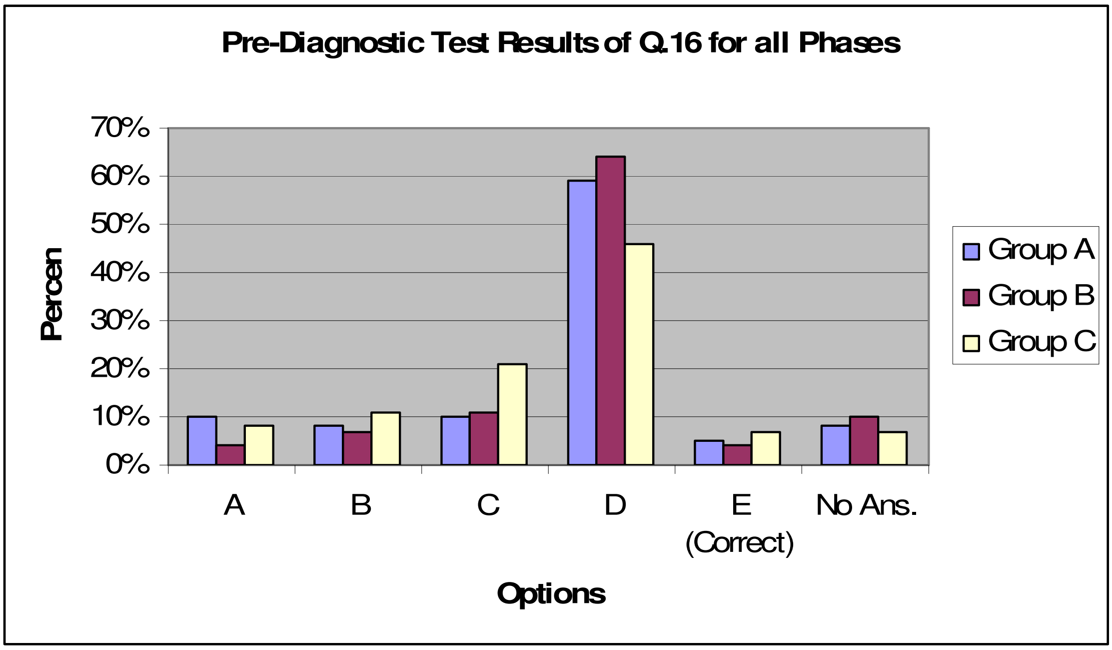


Figure 4.5 Results of Question 16 on the Pre-Diagnostic Test for three Phases n=106.

4.4 Results of Phase 1

Phase 1 (n=16) include results of individual questions on just the pre-diagnostic test, performance of participating students in their concurrent Chemistry module and results of the attitude and confidence test before the Intervention Programme. No online resources were made available during this phase.

4.4.1 Individual Questions in Pre-Diagnostic Test

Students completed a pre-diagnostic test on the first tutorial session of the Intervention Programme. This diagnostic test sought to test students' understanding in general Chemistry concepts and ideas. Results of individual questions will be analysed in this section.

Question 1

Q1. How many atoms are in the formula $Al_2(SO_4)_3$?

3 __

5 __

17 __

Figure 4.6 Question 1 in the Pre-Diagnostic Test.

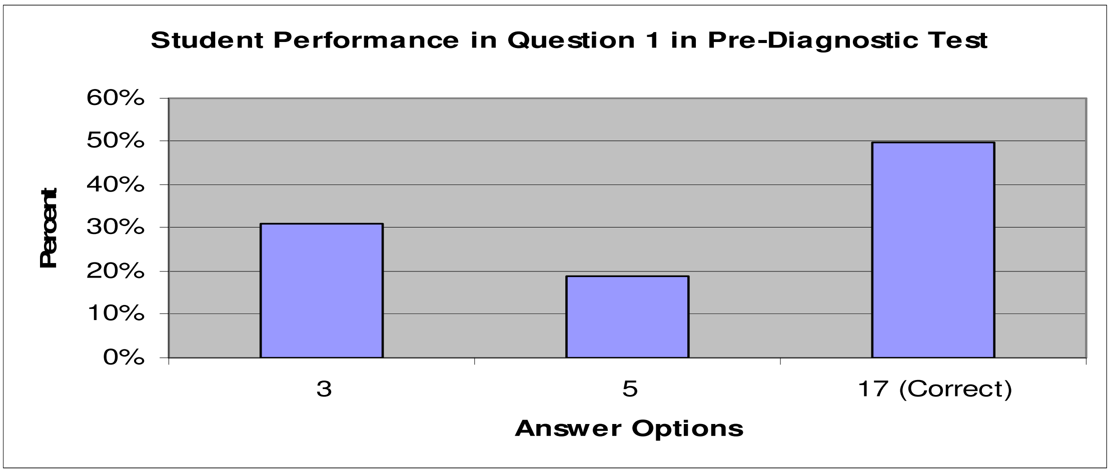


Figure 4.7 Performance of Students in Question 1 in the Pre-Diagnostic Test.

Question 1 (Figure 4.6) asked students to determine how many atoms were present in a particular compound. In order to correctly answer this question, students needed to be familiar with what an atom was and also what the coefficients written beside the symbols meant. 8 (50%) of the students got this question correct, 3 (19%) chose answer 5 and 5 (31%) of the students thought the compound was made up of 3 atoms (see Figure 4.7).

Question 2

Q2. The radioactive isotope ^{14}C has how many neutrons? (z = 6)

6 ___

8 ___

Other ___

Figure 4.8 Question 2 in the Pre-Diagnostic Test.

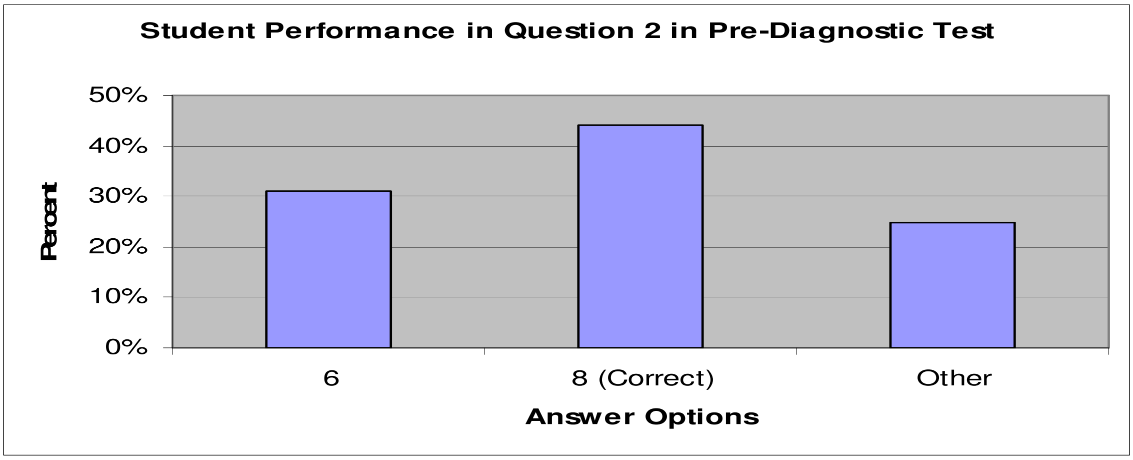


Figure 4.9 Performance of Students in Question 2 in the Pre-Diagnostic Test.

Question 2 (Figure 4.8) asked students to calculate how many neutrons were present in an isotope. To be able to answer this question, students needed to know how to calculate the number of neutrons in an atom and also that the symbol 'Z' represents the atomic number, the number of protons present in an atom. 7 (44%) of the students selected the correct answer of 8, 5 (31%) selected the answer 6 and 4 (25%) of the students selected the answer ''other'' (see Figure 4.9)

Question 3

Q3. The identity of an element is determined by the number of which particle?
Protons ___
Neutrons ___
Electrons ___

Figure 4.10 Question 3 in the Pre-Diagnostic Test.

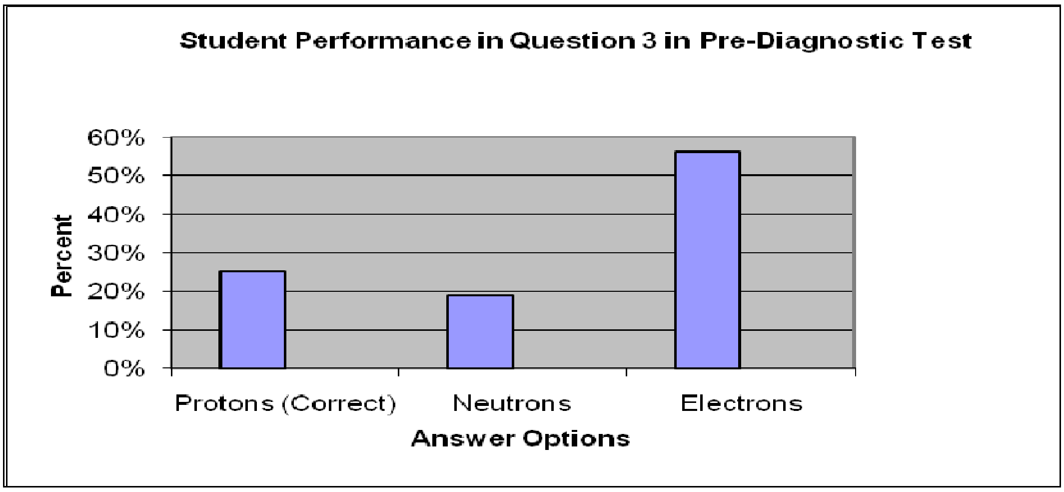


Figure 4.11 Performance of Students in Question 3 in the Pre-Diagnostic Test.

Question 3 (Figure 4.10) tested students' understanding of how an element's identity is determined. In the pre-test, 4 (25%) of the students selected the correct answer, (19%) student chose neutrons and 9 (56%) of the students thought the identity of an element was determined by electrons (see Figure 4.11).

Question 4

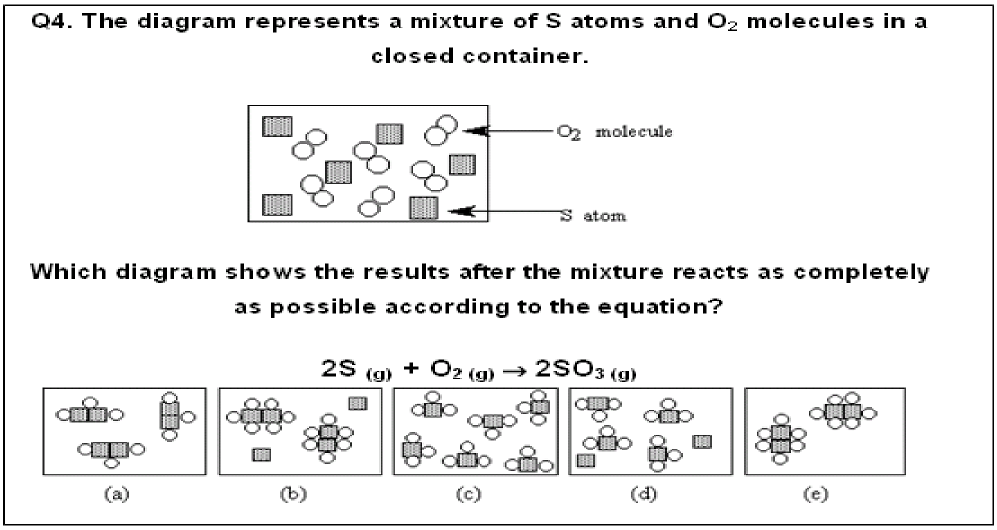


Figure 4.12 Question 4 in the Pre- and Post-Diagnostic Test.

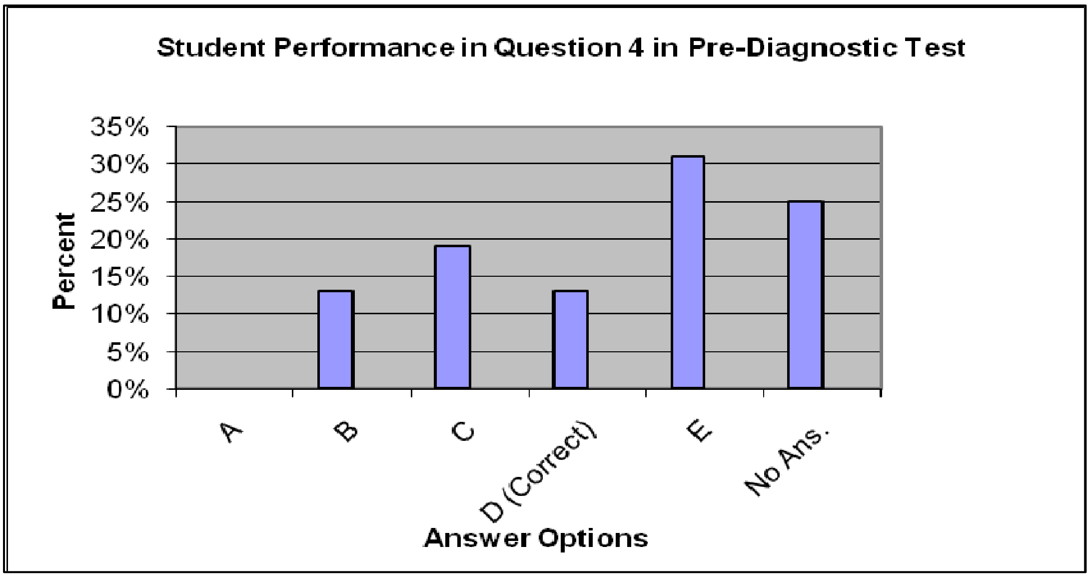


Figure 4.13 Performance of Students in Question 4 in the Pre-Diagnostic Test.

Question 4 (Figure 4.12) sought to test students' understanding about chemical equations. 2 (13%) of the students chose the correct answer D, 10 (63%) of the students selected incorrect answers (B, C or E) in the pre-test. This suggests that students have difficulty understanding the difference between the coefficient '2' and the subscript '3' in $2SO_3$. 4 (25%) of the students did not answer this question (see Figure 4.13).

Question 5

Q5. How many moles of ions are there per 1 mole of $Al_2(SO_4)_3$?
2 ___
3 ___
5 ___

Figure 4.14 Question 5 in the Pre-Diagnostic Test.

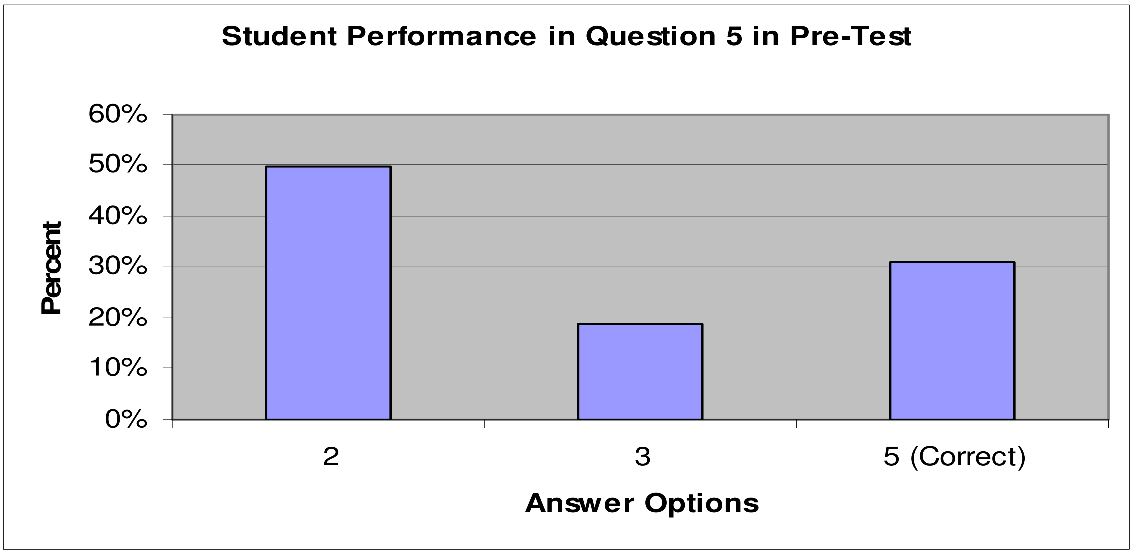


Figure 4.15 Performance of Students in Question 5 in the Pre-Diagnostic Test.

Question 5 (Figure 4.14) asked students to calculate the number of moles of ions in a particular compound. To complete this question correctly, students had to be able to break up the compound into ions. 5 (31%) of the students chose the correct answer 5, 3 (19%) selected answer 3 and 8 (50%) of the students thought that there were 2 mole of ions present in the compound (See Figure 4.15).

Question 6

Q6. Write the electronic configuration (s,p) of Chlorine. (z = 17)

Figure 4.16 Question 6 in the Pre-Diagnostic Test

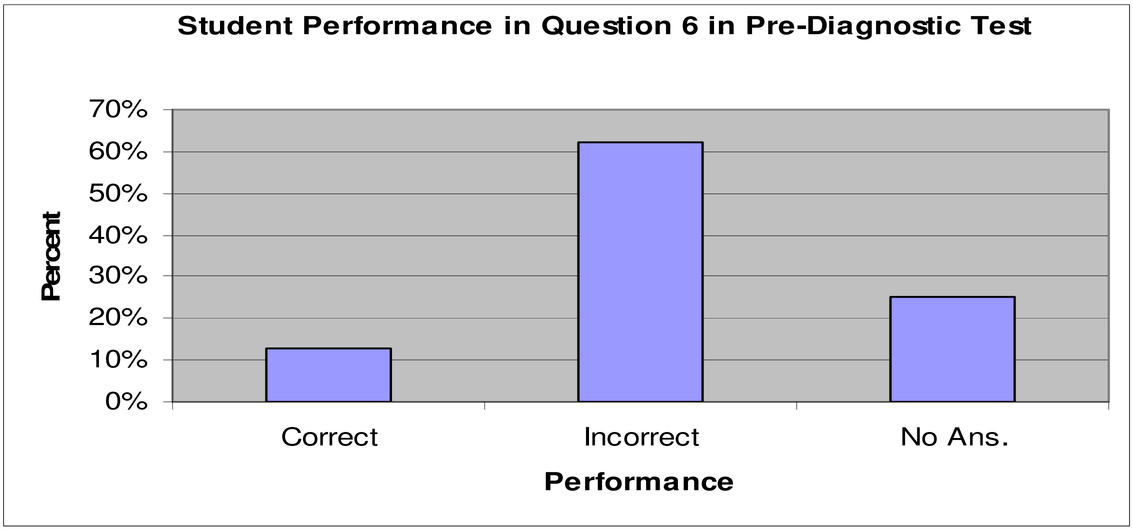


Figure 4.17 Performance of Students in Question 6 in the Pre-Diagnostic Test

Question 6 (Figure 4.16) tested students' ability to correctly write the electronic configuration of Chlorine. To answer this question successfully, students needed to have an understanding of the number of electrons in s and p orbitals. 2 (13%) of students got this question correct, 10 (62%) got this question incorrect and 4 (25%) of students did not answer the question (see Figure 4.17).

Question 7

Q7. How many moles of Aluminium atoms are there in 9 x 10^{22} atoms of aluminium? (Relative Molecular mass Al = 13)

Figure 4.18 Question 7 in the Pre-Diagnostic Test.

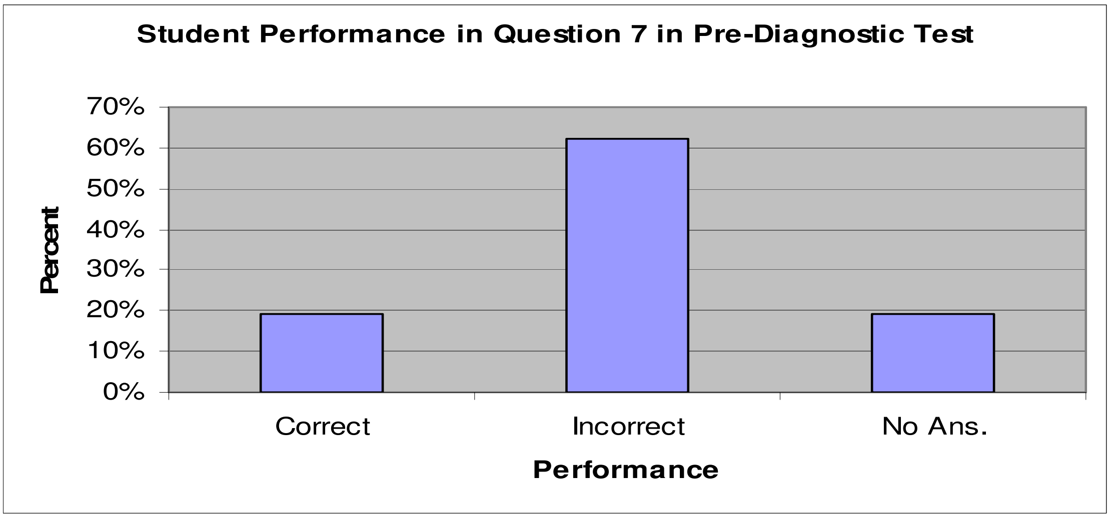


Figure 4.19 Performance of Students in Question 7 in the Pre-Diagnostic Test.

Question 7 (Figure 4.18) examines students' ability to calculate the number of moles of atoms present in 9 x 10^{22} atoms of Aluminium. For this question students need to be familiar with Avogadro's number and it's relation to the mole. 3 (19%) of the students got the question correct, 10 (62%) of the students got it incorrect and 3 (19%) of the students did not answer the question (see Figure 4.19).

Question 8

Q8. Write the formula for Sodium Sulfide

Figure 4.20 Question 8 in the Pre-Diagnostic Test.

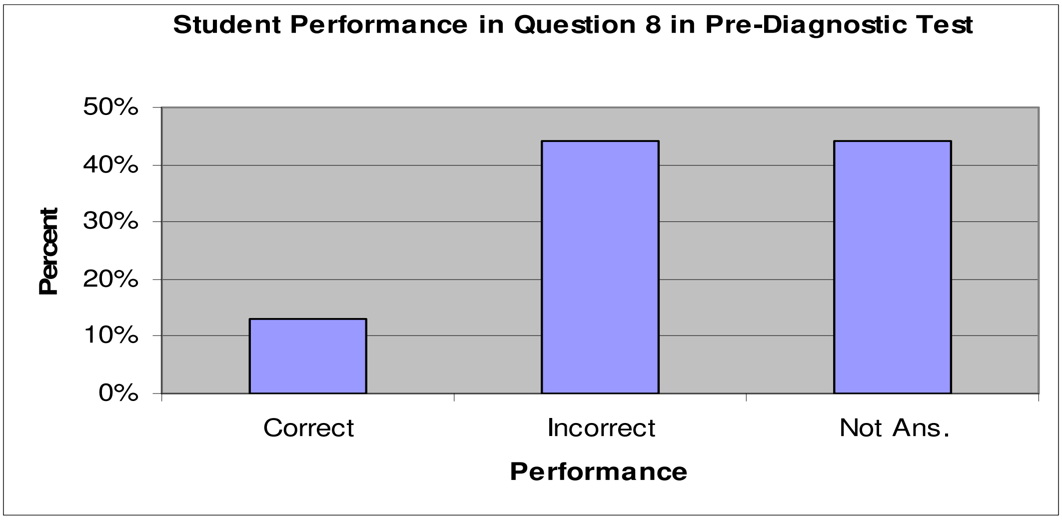


Figure 4.21 Performance of the Students in Question 8 in the Pre-Diagnostic Test.

Question 8 (Figure 4.20) asked students to write the chemical formula for a compound. To correctly answer this question, students needed to be familiar with the charges and formulae of the ions. 2 (13%) of the students got this question correct, 7 (44%) got the question incorrect and 7 (44%) of the students chose not to answer the question (see Figure 4.21).

Question 9

Q9. What is the oxidation number of the N atom in the NO_3^- ion?

Figure 4.22 Question 9 in the Pre-Diagnostic Test.

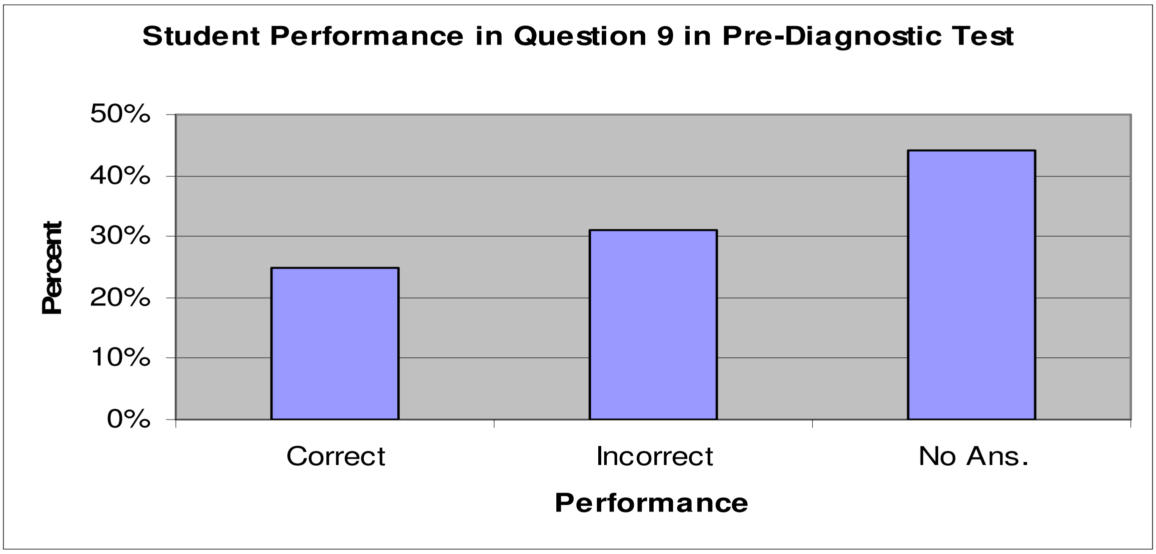


Figure 4.23 Performance of Students in Question 9 in the Pre-Diagnostic Test.

Question 9 (Figure 4.23) students are asked to work out the oxidation number of Nitrogen in a compound. In order to complete this question successfully, students needed to be familiar with the rules for assigning oxidation numbers. 4 (25%) of the students got this question correct, 5 (31%) got this incorrect and 7 (44%) chose not to answer this question (see Figure 4.24).

Question 10

Q10. Use the VSEPR theory to deduce the shape of the ammonia molecule, NH_3

Figure 4.24 Question 10 in the Pre- Diagnostic Test.

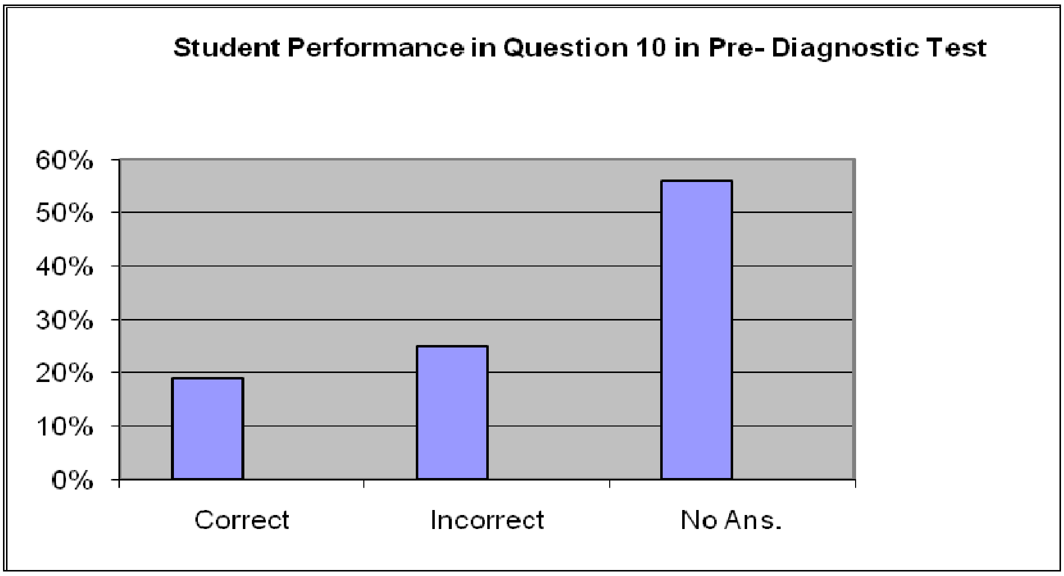


Figure 4.25 Performance of Students in Question 10 in the Pre-Diagnostic Test.

Question 10 (Figure 4.24) asked students to deduce the shape of the ammonia molecule. To answer this question, students needed to be familiar with the type of bonding that the particular molecule had. Only 3 (19%) of the students got the question correct, 4 (25%) of the students got this question incorrect and 9 (56%) of the students chose not to answer this question (see Figure 4.25).

<u>Question 11</u>

Q11. Write the formula of Sodium Sulphate

Figure 4.26 Question 11 in the Pre-Diagnostic Test.

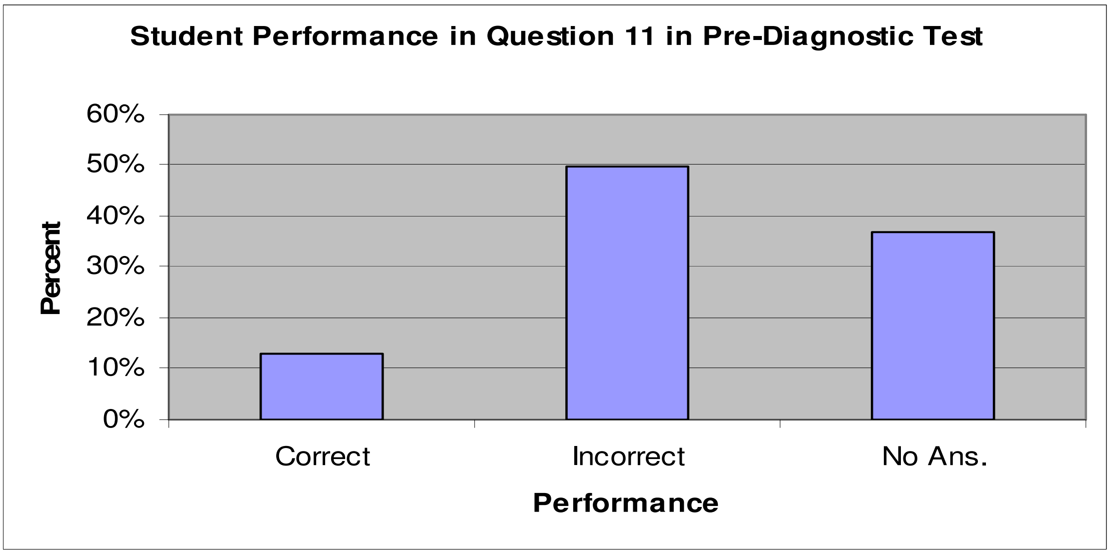


Figure 4.27 Performance of Students in Question 11 in the Pre-Diagnostic Test.

Question 11 (Figure 4.26) asked students to write the chemical formula for a particular compound. To successfully answer this question, students needed to be familiar with the charges on the ions and their formulae. 2 (13%) of the students answered this question correctly, 8 (50%) answered it incorrectly and 6 (37%) of the students did not answer this question (see Figure 4.27).

Question 12

Q12. Balance the following equation
$K_{(s)} + H_2O \rightarrow KOH_{(aq)} + H_{2\,(g)}$

Figure 4.28 Question 12 in the Pre-Diagnostic Test.

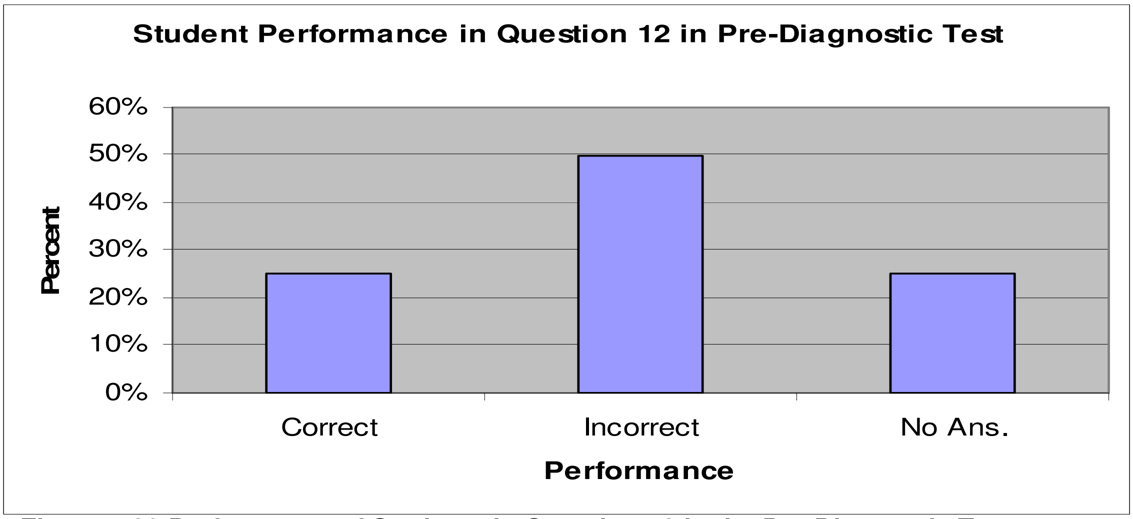


Figure 4.29 Performance of Students in Question 12 in the Pre-Diagnostic Test.

Question 12 (Figure 4.28) asked students to balance an equation. In order to complete this question students needed to be familiar with the difference between coefficients and subscripts used in a chemical equation. 4 (25%) of the students got the question correct, 8 (50%) got it incorrect and 4 (25%) of the students did not answer this question (see Figure 4.29).

Question 13

Q13. Magnesium reacts with oxygen to produce Magnesium oxide according to the equation:

$$2Mg_{(g)} + O_{2\,(g)} \rightarrow 2MgO_{(g)}$$

If a student burns 9g of magnesium in excess oxygen (i.e. there is plenty of oxygen present to ensure that all of the magnesium reacts), what mass of Magnesium Oxide will be formed?

Figure 4.30 Question 13 in the Pre-Diagnostic Test.

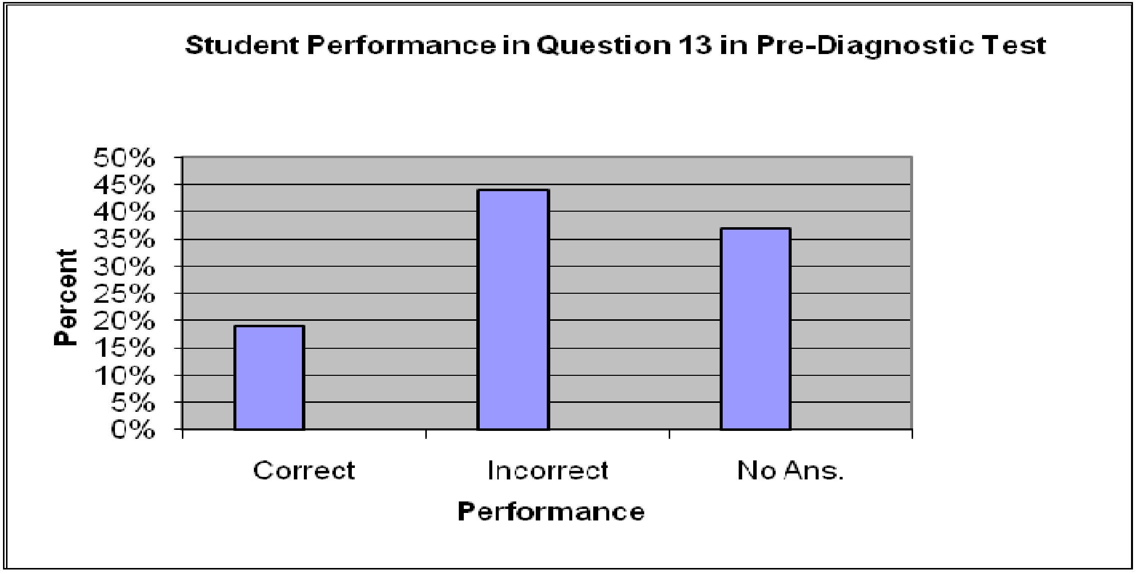


Figure 4.31 Performance of Students in Question 13 in the Pre-Diagnostic Test.

Question 13 (Figure 4.30) tested students' ability to complete chemical calculations using the chemical equation for the reaction. To answer this question successfully students needed to have an understanding of the mole relationship in the equation. 3 (19%) of the students got this question correct, 7(44%) got this question incorrect, 6 (37%) of the students chose not to answer this question (see Figure 4.31).

<u>Question 14</u>

Q14. Which of the flasks below will contain a mixture when all the hydrogen reacts with oxygen to give water? (H_2O)

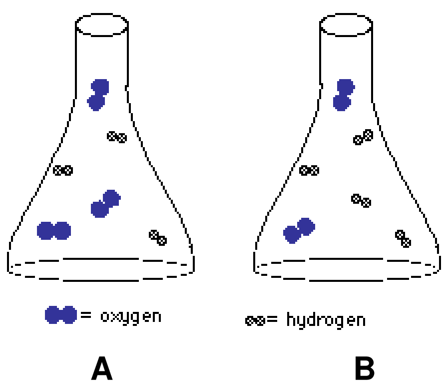


Figure 4.32 Question 14 in the Pre-Diagnostic Test.

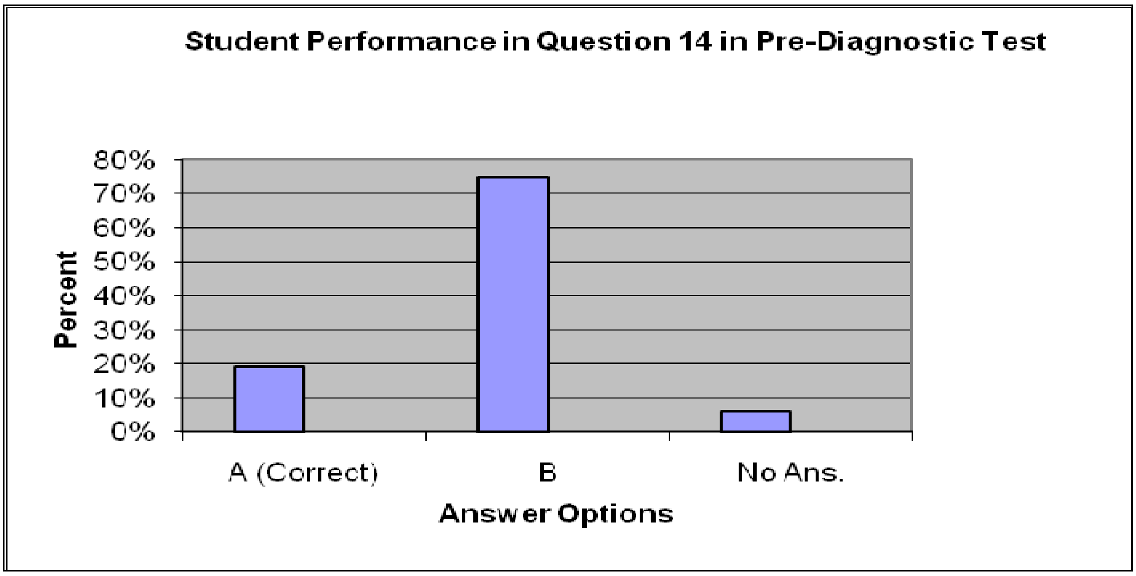


Figure 4.33 Performance of Students in Question 14 in Pre-Diagnostic Test.

Question 14 (Figure 4.32) asked students to determine which flask would contain a mixture when all the Hydrogen reacts with the Oxygen. In order to complete this question successfully, students needed to have a clear understanding of what a mixture is and the stoichiometry of the reaction. 3 (19%) of students chose the correct answer, 12 (75%) of the students chose the incorrect answer, 1 (6%) did not attempt this question (see Figure 4.33).

<u>Question 15</u>

Q15. Drops of water and ethanol are placed on an overhead projector and the ethanol drop is seen to evaporate more rapidly. The graph below compares the vapour pressures of ethanol and water. Which curve corresponds to ethanol?

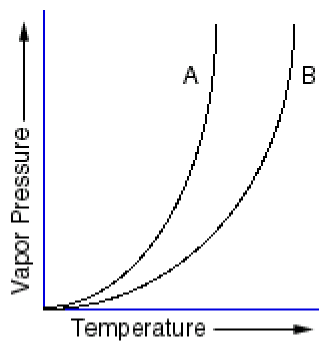


Figure 4.34 Question 14 in the Pre-Diagnostic Test.

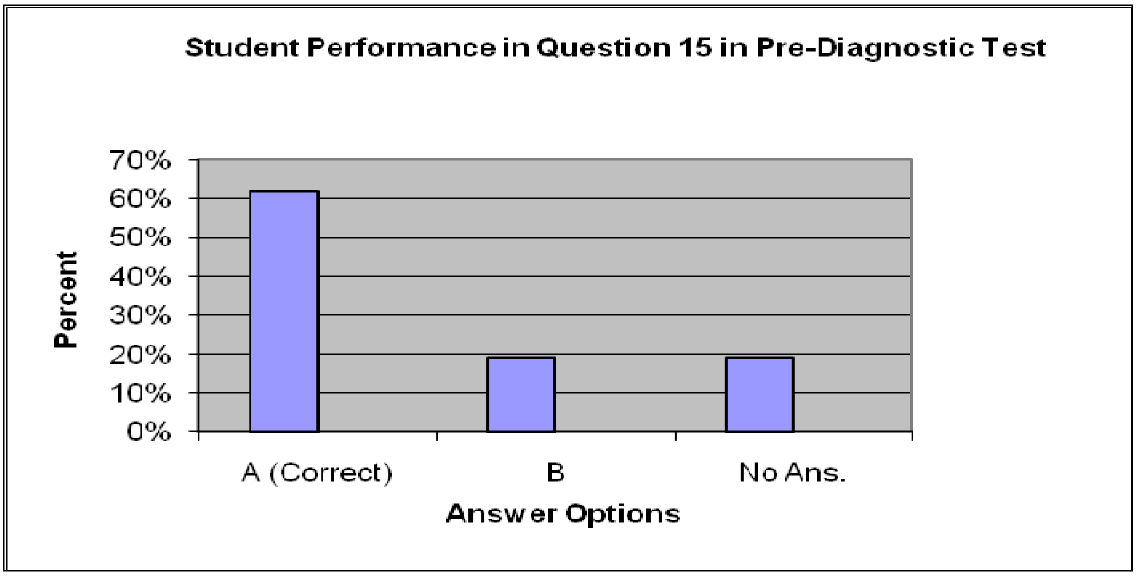
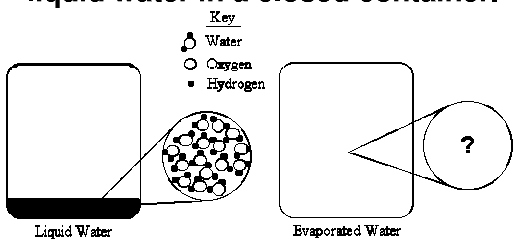


Figure 4.35 Performance of Students in Question 15 in Pre-Diagnostic Test.

In question 15 (Figure 4.34) students are asked to determine whether ethanol or water evaporates first. In order to complete this question students need to be able to analyse the graph correctly and relate vapour pressure and boiling point. 10 (62%) of the students got this question correct, 3 (19%) got this question incorrect and 3 (19%) chose not to answer this question (see Figure 4.35).

Question 16

Q16. The circle on the left shows a magnified view of a very small portion of liquid water in a closed container.



What would the magnified view show after the water evaporates?

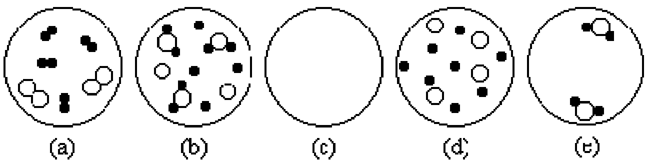


Figure 4.36 Question 16 in the Pre-Diagnostic Test.

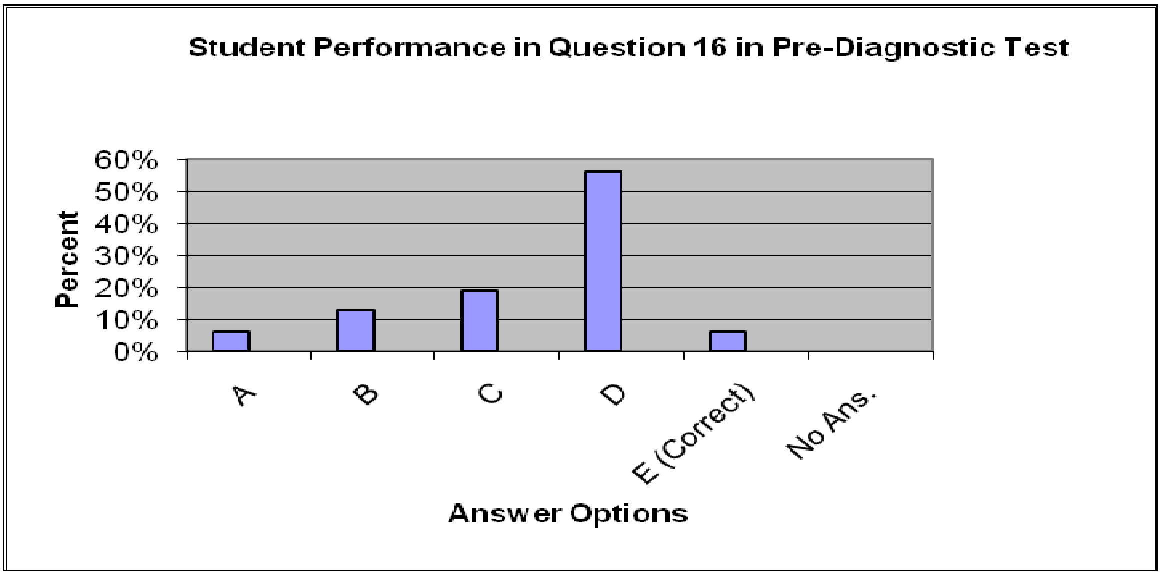


Figure 4.37 Performance of Students in Question 16 in the Pre-Diagnostic Test.

Question 16 (Figure 4.36) tested students' understanding of what happens to a water molecule when it evaporates. To answer this question correctly students needed to be familiar with what a molecule was and the states of matter. 1 (6%) of the students got this question correct, choosing option E, 15 (94%) of the students got this question incorrect and all students answered this question. The most common answer on the pre-test for this question was option D. This shows that students believe that Hydrogen and Oxygen split into individual atoms when they evaporate (see Figure 4.37).

4.4.2 Individual Questions in Post-Diagnostic Test

As students from Phase 1 did not attend the last tutorial session when the post-diagnostic testing was taking place, there are no post-diagnostic test results to be discussed.

4.4.3 Overall Performance in Pre- and Post-Diagnostic Test

Again, due to the lack of attendance of students during the post-diagnostic testing session, performance in the pre-test could not be compared to performance in the post-test.

4.4.4 Results from the Concurrent Chemistry Module

During Phase 1 of the Intervention Programme, Group A and Group B were concurrently studying an 'Inorganic Chemistry' module and Group C were studying an ‘Analytical Chemistry’ module. The performance of students (who attended six or more of the Intervention Programme tutorials) in the written part of these examinations was analysed. In total, 25 students were looked at. It should be noted that not all of these students had completed a pre-diagnostic test and none had completed a post-diagnostic test. The percentage refers to the performance on the final examination and excludes coursework marks.

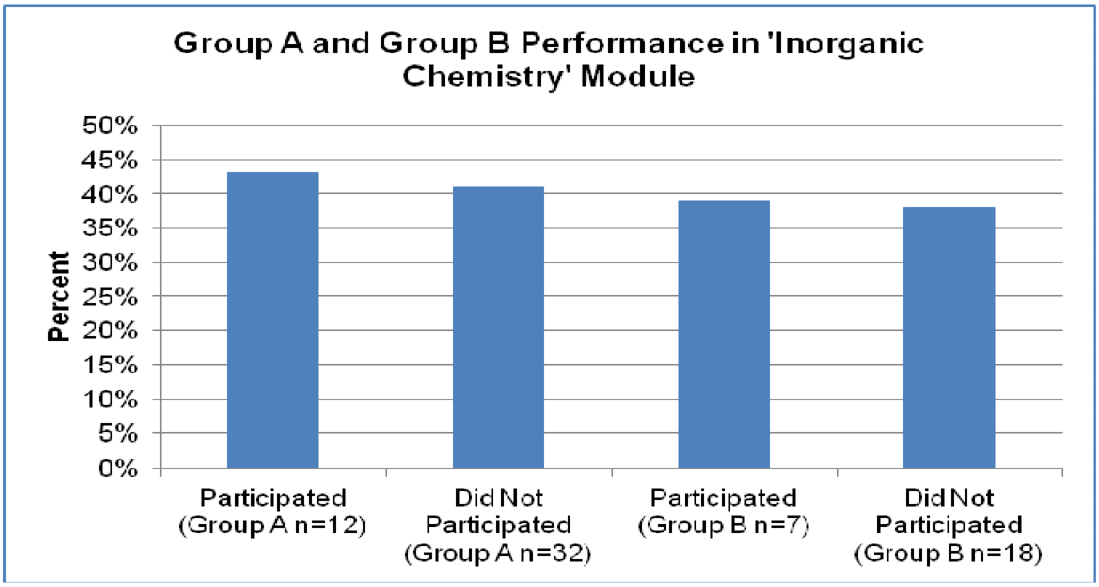


Figure 4.38 Performance of Group A and Group B in the concurrent Chemistry Module.

On average, in the ‘Inorganic Chemistry’ module, students that attended six or more tutorials did better than their peers in the same course who did not attend. Group A experienced slightly higher grades (M =42.92, SE =3.38) than those who did not take part in the intervention programme (M =40.81, SE = 3.22). This difference was not significant p = 0.247; however it did represent a small to medium size effect r = 0.27. Group B experienced slightly better grades (M =39.10, SE =2.51) than those in the group who did not take part in the intervention programme (M = 37.84, SE =3.47). This difference was not significant p = 0.626; there was also a small to medium size effect r =0.29.

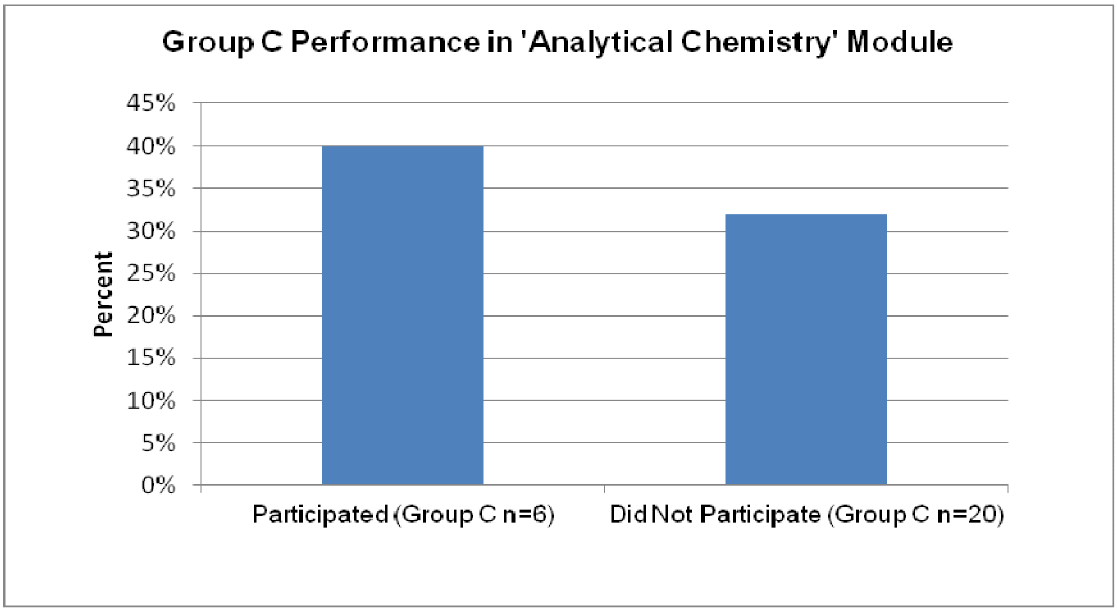


Figure 4.39 Performance of Group C in the concurrent Chemistry Module.

Group C experienced slightly better grades (M = 40.69, SE = 2.56) than those in the group who did not take part in the intervention programme (M = 31.24, SE = 3.47). This difference was not significant p = 0.138; however it did represent a small to medium size effect r = 0.27.

4.4.5 Results from Attitude and Confidence Test

Pre-attitude and confidence test results will be presented in this section as this is the only data available for this group. As can be seen from Table 4.6, in the pre-attitude and confidence test, student's had 'Very Low' confidence level in 'Choosing an appropriate formula to solve a problem', 'Determining the appropriate units to use in a result' and 'Applying their knowledge of Chemistry to the real world'. Students had 'Low' confidence in'Understanding key concepts of Chemistry', 'Approaching a Chemistry problem', 'Tutoring another student in first year Chemistry course' and 'Succeeding in a Chemistry-related discipline'. Students had 'Average' confidence level in 'Understanding other areas of Science' and also 'Succeeding in their Chemistry course'. Students had 'High' confidence levels in 'Reading the procedure and carrying out an experiment without supervision'.

Table 4.6 Results of Pre-Attitude and Confidence Test for Phase 1 n=16.

	Mean	25th Percentile	**Median 50th Percentile**	75th Percentile	General Trend
Understand key concepts of Chemistry and explain topics in own words	2.16	2	**2**	2	Low Confidence
Choosing an appropriate formula to solve a Chemistry problem	1.69	2	**1**	2	Very Low Confidence
Approach a Chemistry problem in a systematic manner, working step by step	2.56	3	**2**	2	Low Confidence
Determine the appropriate units for a result determined using a formula	2.16	2	**1**	2	Very Low Confidence
Read the procedures for an experiment and conduct the experiment without supervision	3.89	3	**4**	4	**High Confidence**
Tutor another student in a first year Chemistry course	3.11	3	**2**	2	Low Confidence
Apply your knowledge of Chemistry to the real world	1.88	2	**1**	2	Very Low Confidence
Understand other areas of Science	2.78	3	**3**	2	Average Confidence
Succeed in this Chemistry course	2.96	2	**3**	3	Average Confidence
Succeed in a Chemistry-related discipline	2.65	2	**2**	3	Low Confidence

4.5 Results from Phase 2

The results of Phase 2 will now be presented. This phase was made up of two parts and will each be presented separately. Results include performance in individual questions on both the pre- and the post-diagnostic test, overall performance in the diagnostic tests, performance of participating students in their concurrent Chemistry modules, results of the attitude and confidence test before and after the Intervention Programme and usage of online resources made available during both parts of Phase 2. Also, results from the interviews that were carried out at the end of Phase 2 will be presented.

4.5.1 Part 1

Part 1 (n=20) was similar to Phase 1, already discussed as it also focused on basic Chemistry concepts and ideas. It used the same pre-diagnostic test as Phase 1. This part was successful however, as 35 students attended the last tutorial session to take part in the post-diagnostic testing session.

4.5.1.1 Individual Questions in Pre-Diagnostic Test

As outlined above, the same pre-diagnostic test as Phase 1 was used for Part 1. As the questions from both the pre-diagnostic test are already outlined above in section 4.3.1, they will not be discussed here. Instead, a table containing the results will be used.

Table 4.7 Performance in Individual Questions in Pre- and Post-Diagnostic Test.

n=20	Pre-Diagnostic Test		
Question	Correct	Incorrect	No Ans.
1	10 (50%)	10 (50%)	0 (0%)
2	7 (35%)	13 (65%)	0 (0%)
3	3 (15%)	17 (85%)	0 (0%)
4	1 (5%)	16 (80%)	0 (0%)
5	6 (30%)	14 (70%)	0 (0%)
6	2 (10%)	12 (60%)	6 (30%)
7	3 (15%)	9 (45%)	8 (40%)
8	0 (0%)	12 (60%)	8 (40%)
9	6 (30%)	9 (45%)	5 (25%)
10	2 (10%)	6 (30%)	12 (60%)
11	0 (0%)	13 (65%)	7 (35%)
12	7 (35%)	9 (45%)	4 (20%)
13	2 (10%)	16 (80%)	2 (10%)
14	6 (30%)	10 (50%)	4 (20%)
15	15 (75%)	4 (20%)	1 (5%)
16	3 (15%)	13 (65%)	4 (20%)

4.5.1.2 Individual Questions in Post-Diagnostic Test

Individual results from the post-diagnostic test for part 1 will now be analysed. Some of the questions from the post-diagnostic test were also used on the pre-test (Question 3, 4, 10, 13, 14, 15,16) and have been accounted for in the pre-test results (Figure 4.58).

Question 1

Q1. How many atoms are in the formula $Na_2Cr_2O_7$?
4 __
11 __
15 __

Figure 4.40 Question 1 in the Post-Diagnostic Test.

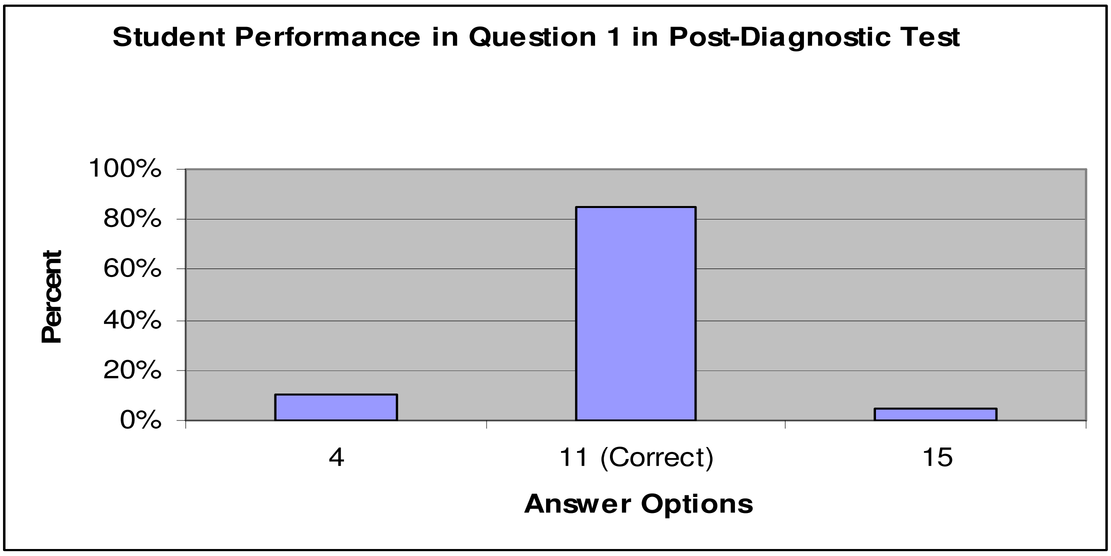


Figure 4.41 Performance of Students in Question 1 in the Post-Diagnostic Test.

This question asked students to determine how many atoms were present in a particular compound. In order to correctly answer this question, students needed to be familiar with what an atom was and also what the coefficients written beside the symbols meant. 17 (85%) of the students got this question correct, 2 (10%) chose answer 4 and 1 (5%) of the students thought the compound was made up of 15 atoms.

Question 2

Q2. The radioactive isotope ^{22}Ne has how many neutrons? (z = 10)
12___
10___

Other ___

Figure 4.42 Question 2 in the Post-Diagnostic Test.

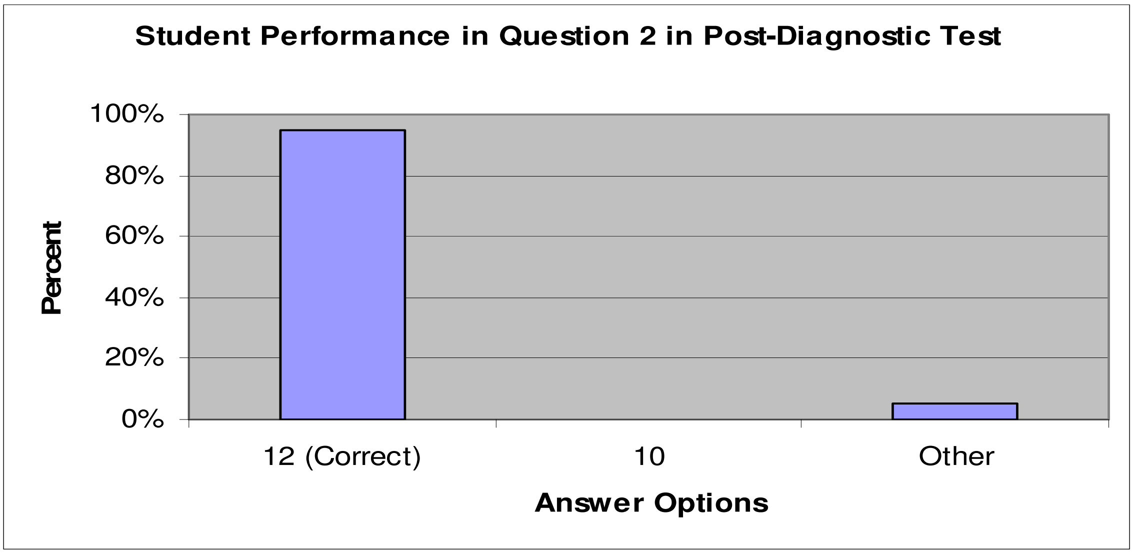


Figure 4.43 Performance of Student in Question 2 in the Post-Diagnostic Test.

This question asked students to calculate how many neutrons were present in an isotope. To be able to answer this question, students needed to know how to calculate the number of neutrons in an atom and also that the symbol 'Z' represents the atomic number, the number of protons present in an atom. 19 (95%) of the students selected the correct answer of 12, none of the students selected the answer 10 and 1 (5%) selected option 'Other'.

Question 5

Q5. How many moles of ions are there per 1 mole of $NaHCO_3$?

2 ___

3 ___

5 ___

Figure 4.44 Question 5 in the Post-Diagnostic Test.

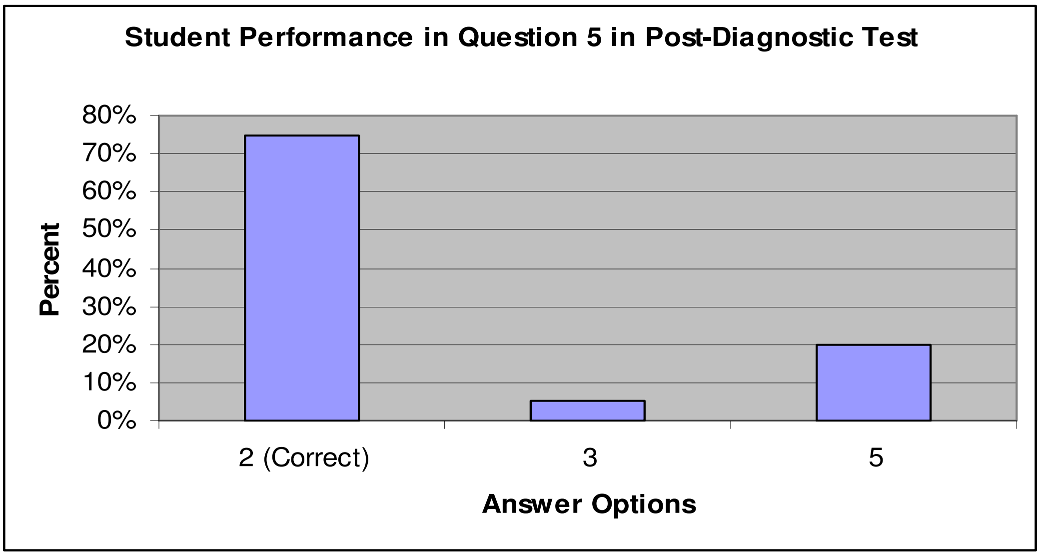


Figure 4.45 Performance of Students in Question 5 in the Post-Diagnostic Test.

This question asked students to calculate the number of moles of ions in a particular compound. To complete this question correctly, students had to be able to break up the compound into ions. 15 (75%) of the students chose the correct answer 2, 1 (5%) selected answer 3 and 4 (20%) of the students thought that there were 5 mole of ions present in the compound.

Question 6

Q6. Write the electronic configuration (s,p) of S. (z = 16)

Figure 4.46 Question 6 in the Post-Diagnostic Test.

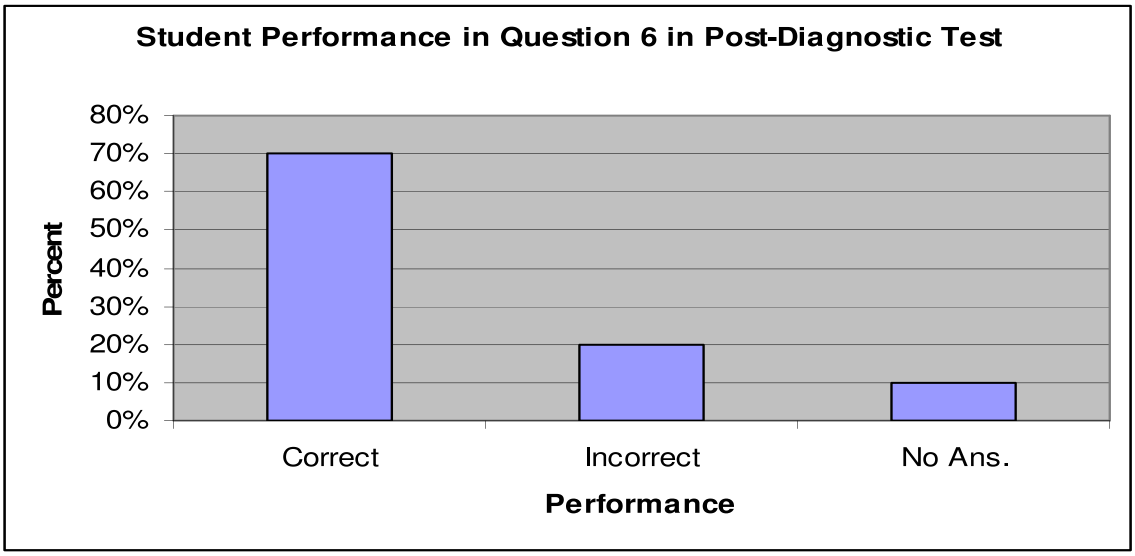


Figure 4.47 Performance of Students in Question 6 in the Post-Diagnostic Test.

This question tested students' ability to correctly write the electronic configuration of Sulfur. To answer this question successfully, students needed to have an understanding of the number of electrons in s and p orbitals. 14 (70%) of students got this question correct, 4 (20%) got this question incorrect and 2 (10%) of students did not answer the question.

Question 7

Q7. How many moles of Carbon atoms are there in 9 x 10^{22} atoms of carbon?

Figure 4.48 Question 7 in the Post-Diagnostic Test.

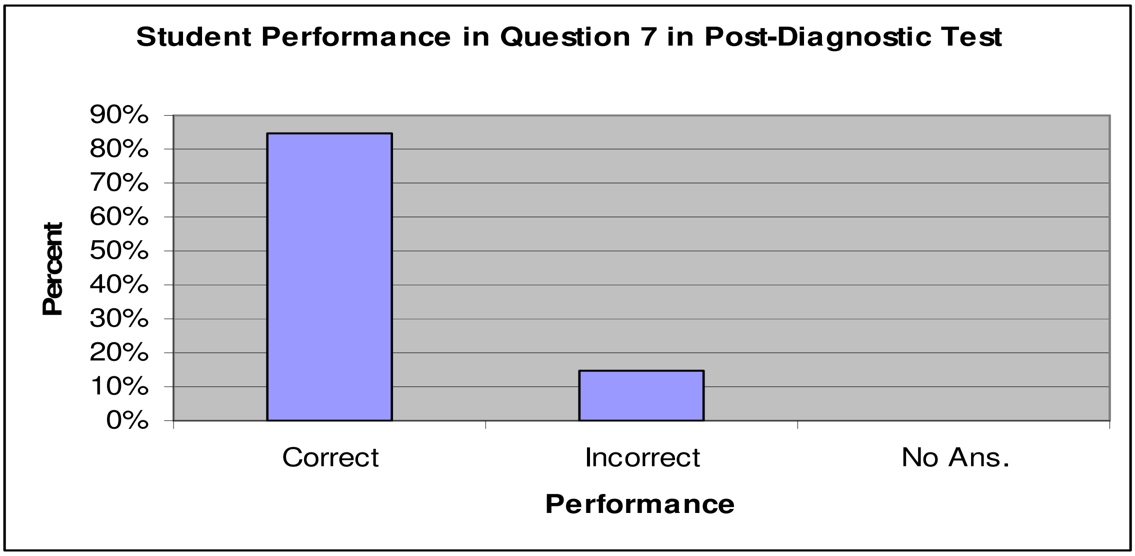


Figure 4.49 Performance of students in Question 7 in the Post-Diagnostic Test.

This question examines students' ability to calculate the number of moles of atoms present in 9 x 10^{22} atoms of Carbon. For this question students need to be familiar with Avogadro's number and the mole. 17 (85%) of the students got the question correct, 3 (15%) of the students got it incorrect.

Question 8

Q8. Write the formula for Sodium Carbonate

Figure 4.50 Question 8 in the Post-Diagnostic Test.

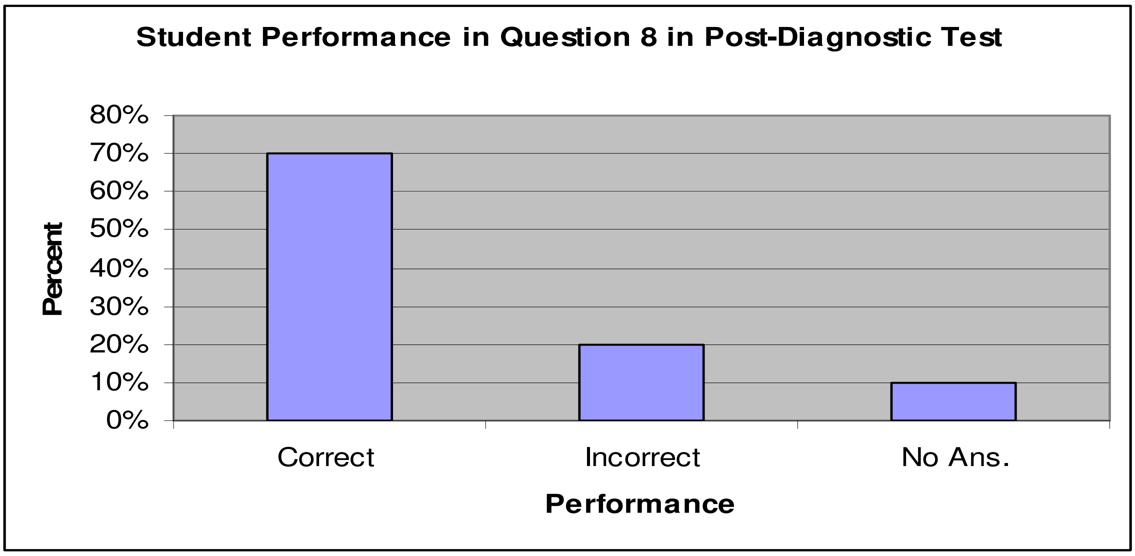


Figure 4.51 Performance of Students in Question 8 in the Post-Diagnostic Test.

This question asked students to write the chemical formula for a compound. To correctly answer this question, students needed to be familiar with the charges and formulae of the ions. 14 (70%) of the students got this question correct, 4 (20%) got the question incorrect and 2 (10%) of the students chose not to answer the question.

Question 9

Q9. What is the oxidation number of Sulfur in $Na_2S_2O_3$?

Figure 4.52 Question 9 in the Post-Diagnostic Test.

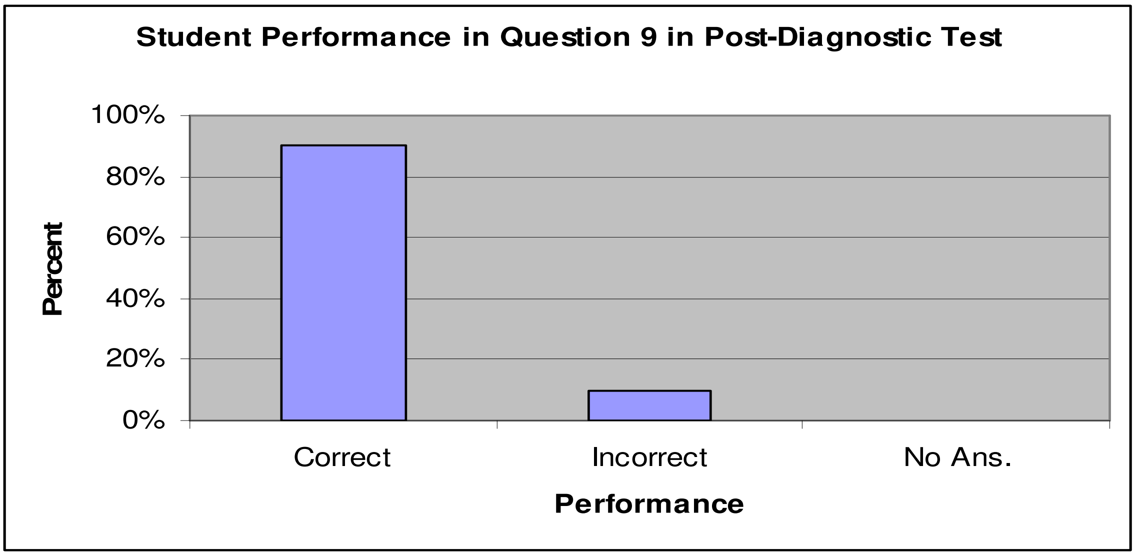


Figure 4.53 Performance of Students in Question 9 in Post-Diagnostic Test.

In this question, students are asked to work out the oxidation number of Sulfur in a compound. In order to complete this question successfully students needed to be familiar with the rules for assigning oxidation numbers and the charges and formulae of the ions. 18 (90%) of the students got this question correct, 2 (10%) got this incorrect.

<u>Question 11</u>

Q11. Write the formula of Calcium Carbide?

Figure 4.54 Question 11 in the Post-Diagnostic Test.

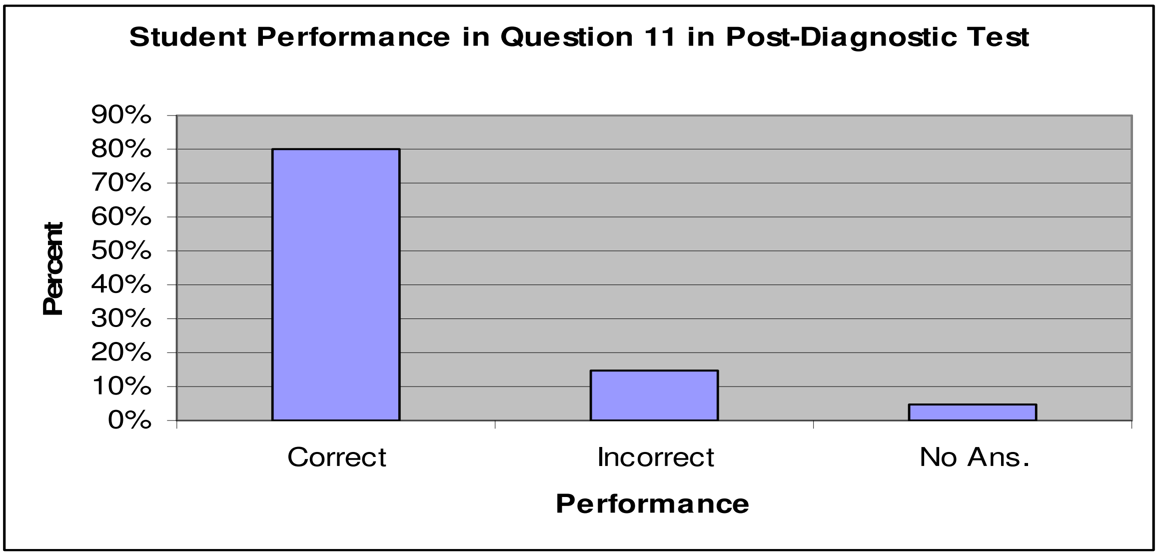


Figure 4.55 Performance of Students in Question 11 in the Post-Diagnostic Test.

This question asked students to write the chemical formula for a particular compound. To successfully answer this question, students needed to be familiar with the charges and formulae of the ions. 16 (80%) of the students answered this question correctly, 3 (15%) answered it incorrectly and 1 (5%) did not answer this question.

<u>Question 12</u>

Q12. Balance the following equation
$HNO_{3\ (aq)} + Ca(OH)_{2\ (s)} \rightarrow Ca(NO_3)_{2\ (aq)} + H_2O_{(aq)}$

Figure 4.56 Question 12 on the Post-Diagnostic Test.

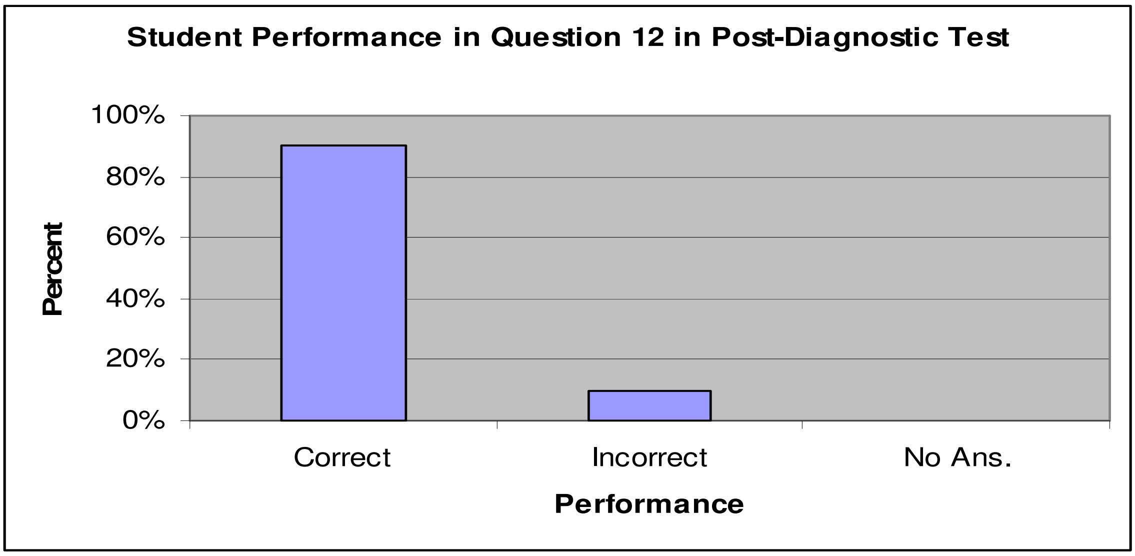


Figure 4.57 Performance of Students in Question 12 in the Post-Diagnostic Test.

This question asked students to balance an equation. In order to complete this question students needed to be familiar with the difference between coefficients and subscripts used in a chemical equation. 18 (90%) of the students got the question correct, 2 (10%) got it incorrect.

4.5.1.3 Overall Performance in Pre- and Post-Diagnostic Test

The students' overall performance in the pre- and post- diagnostic tests are shown in Figure 4.58, where their percentage of correct answers is shown.

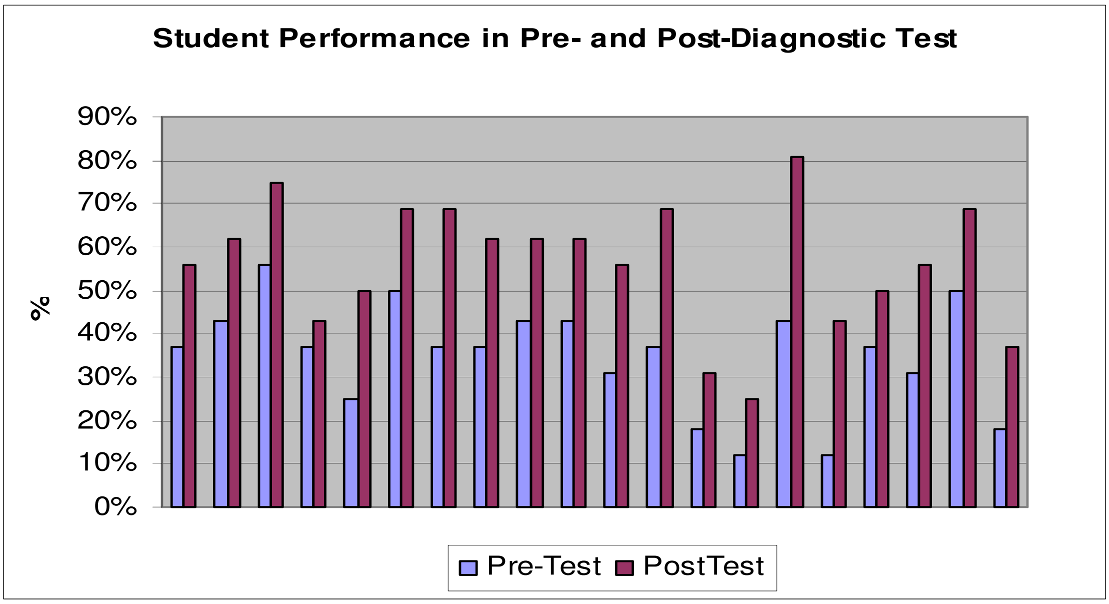


Figure 4.58 Performance of Students in the Pre- and Post-Diagnostic Test n=20.

Participants in Group A experienced significantly higher scores in the post-test after taking part in Phase 1 of the Intervention Programme. (M will be used as an abbreviation for the mean and SE will be used for standard error, M=64.1, SE=1.89, *p = 0.000*) than in the pre-test (M=39.7, SE=2.32). Group A had the highest attendance, attending 72% of the tutorials. Participants in Group B experienced higher scores in the post-test after taking part in the programme (M=48.2, SE=11.9, *p = 0.320*) than in the pre-diagnostic test (M=39.6, SE=5.04), though this was not significant. Group B showed the lowest attendance rate for Part 1, attending 59% of the tutorials. Participants in Group C also experienced significantly higher scores in the post-test after taking part in the programme (M=49.0, SE=6.75, *p = 0.000*) than in the pre-test (M=27.6, SE=5.19). Group C attended 68% of tutorials.

4.5.1.4 Results from Concurrent Chemistry Modules

During Phase 2, Part 1 of the Intervention Programme, Group A were concurrently studying an 'Introductory Physical Chemistry' module and Group B and Group C were studying a 'General Chemistry 2' module. The performance of students (who attended six or more of the Intervention Programme tutorials) in the written part of these examinations was analysed. In total, 32 students were looked at. However, not all of these students had completed a pre-diagnostic test and only some had completed a post-diagnostic test.

On average, in the 'Inorganic Chemistry' module, students that attended six or more tutorials did better than their peers in the same course who did not attend.

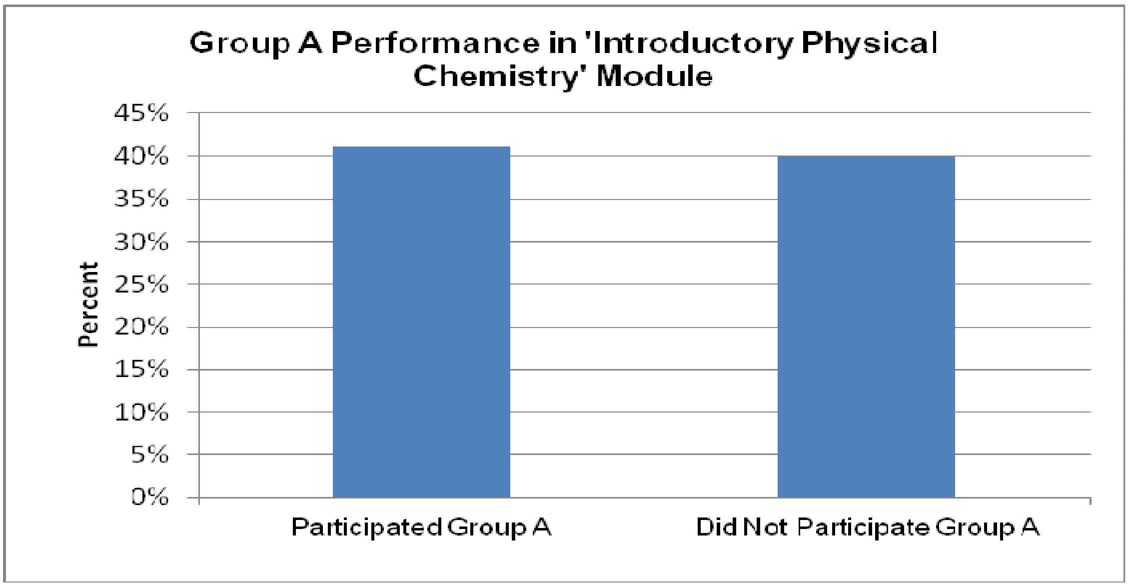


Figure 4.59 Performance of Group A in the concurrent Chemistry Module

Group A experienced slightly higher grades (M =40.85, SE =3.18) than those who did not take part in the intervention programme (M =40.11, SE = 3.22). This difference was not significant p = 0.626; however it did represent a small to medium size effect r = 0.27.

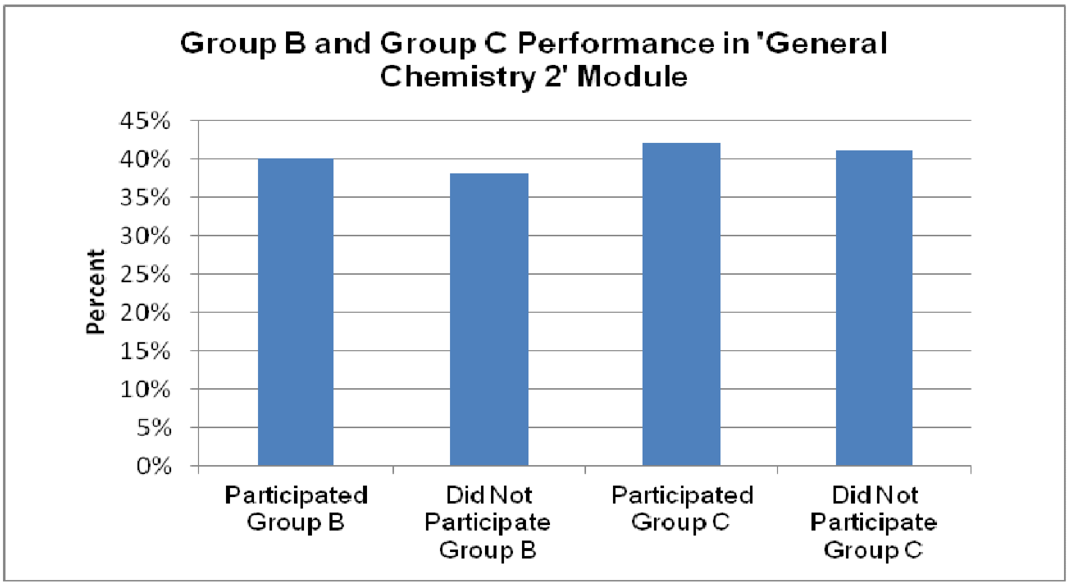


Figure 4.60 Performance of Group B and Group C in the concurrent Chemistry module

Group B experienced slightly better grades (M =40.50, SE =2.51) than those in the group who did not take part in the intervention programme (M = 37.84, SE =3.47). This difference was significant p = 0.001; there was also a small to medium size effect r =0.29. Group C experienced slightly better grades (M =42.35, SE =2.51) than those in the group who did not take part in the intervention programme (M = 40.84, SE =2.67). This difference was not significant p = 0.320.

4.5.1.5 Results from Attitude and Confidence Test

Results from the pre- and post-attitude and confidence tests will now be looked at. The same test was used to see if participation in the Intervention Programme had a positive influence on students' attitudes and confidence levels. As can be seen from Table 4.8 in the pre-attitude and confidence test, student's had 'Very Low' confidence level in 'Choosing an appropriate formula to solve a problem' and 'Applying their knowledge of Chemistry to the real world'. Students had 'Low' confidence in 'Understanding key concepts of Chemistry', 'Approaching a Chemistry problem', 'Determining the appropriate units to use in a result', 'Tutoring another student in first year Chemistry course' and 'Succeeding in their Chemistry courses'. Students had 'Average' confidence level in 'Reading the procedure and carrying out an experiment without supervision', 'Understanding other areas of Science' and also 'Succeeding in a Chemistry-related discipline'. These students did not show 'High' or 'Very High' in any area.

Table 4.8 Results of Pre-Attitude and Confidence Test for Phase 2-Part 1.

	Mean	25th Percentile	**Median 50th Percentile**	75th Percentile	General Trend
Understand key concepts of Chemistry and explain topics in own words	2.59	2	**2**	2	Low Confidence
Choosing an appropriate formula to solve a Chemistry problem	1.96	2	**1**	2	Very Low Confidence
Approach a Chemistry problem in a systematic manner, working step by step	2.39	3	**2**	2	Low Confidence
Determine the appropriate units for a result determined using a formula	2.74	3	**2**	3	Low Confidence
Read the procedures for an experiment and conduct the experiment without supervision	3.64	3	**3**	3	Average Confidence
Tutor another student in a first year Chemistry course	3.58	3	**2**	2	Low Confidence
Apply your knowledge of Chemistry to the real world	1.66	2	**1**	2	Very Low Confidence
Understand other areas of Science	1.33	2	**3**	2	Average Confidence
Succeed in this Chemistry course	3.22	2	**2**	3	Low Confidence
Succeed in a Chemistry-related discipline	2.64	3	**3**	2	Average Confidence

Table 4.9 Results of Post-Attitude and Confidence Test for Phase 2-Part 1.

	Mean	25th Percentile	**Median 50th Percentile**	75th Percentile	General Trend
Understand key concepts of Chemistry and explain topics in own words	3.46	3	**3**	2	Average Confidence
Choosing an appropriate formula to solve a Chemistry problem	2.84	2	**3**	2	Average Confidence
Approach a Chemistry problem in a systematic manner, working step by step	3.59	3	**4**	4	**High Confidence**
Determine the appropriate units for a result determined using a formula	3.49	4	**4**	3	**High Confidence**
Read the procedures for an experiment and conduct the experiment without supervision	3.64	4	**5**	4	**Very High Confidence**
Tutor another student in a first year Chemistry course	3.58	3	**4**	4	**High Confidence**
Apply your knowledge of Chemistry to the real world	2.63	2	**3**	3	Average Confidence
Understand other areas of Science	1.91	2	**3**	2	Average Confidence
Succeed in this Chemistry course	3.34	2	**3**	3	Average Confidence
Succeed in a Chemistry-related discipline	2.76	3	**3**	2	Average Confidence

Table 4.9 shows the results of the post-attitude and confidence test. Students had 'Average' confidence levels in 'Understanding key concepts of Chemistry', 'Choosing an appropriate formula to solve a problem', 'Applying their knowledge of Chemistry to the real world', 'Understanding other areas of Science', 'Succeeding in their Chemistry courses' and also 'Succeeding in a Chemistry-related discipline'. Students had 'High' confidence in 'Approaching a Chemistry problem', 'Determining the appropriate units to use in a result' and 'Tutoring another student in a first year Chemistry course'. Students had 'Very High' confidence level in 'Reading the procedure and carrying out an experiment without supervision'.

Table 4.10 Comparaison of pre- and post-attitude and Confidence Tests.

	Pre-Attitude and Confidence Test	*Post-Attitude and Confidence Test*
	General Trend	*General Trend*
Understand key concepts of Chemistry and explain topics in own words	Low Confidence	Average Confidence
Choosing an appropriate formula to solve a Chemistry problem	Very Low Confidence	Average Confidence
Approach a Chemistry problem in a systematic manner, working step by step	Low Confidence	**High Confidence**
Determine the appropriate units for a result determined using a formula	Low Confidence	**High Confidence**
Read the procedures for an experiment and conduct the experiment without supervision	Average Confidence	**Very High Confidence**
Tutor another student in a first year Chemistry course	Low Confidence	**High Confidence**
Apply your knowledge of Chemistry to the real world	Very Low Confidence	Average Confidence
Understand other areas of Science	Average Confidence	Average Confidence
Succeed in this Chemistry course	Low Confidence	Average Confidence
Succeed in a Chemistry-related discipline	Average Confidence	Average Confidence

From Table 4.10, it can be seen that after the Intervention Programme, the students' attitudes and confidence increased in eight of the ten statements. Confidence levels remained at 'Average', before and after the Intervention

Programme for only two statements, ‘Understanding other areas of Science’ and also ‘Succeeding in a Chemistry-related discipline’.

4.5.1.6 Online Resources

Online resources were made available during Part 1 of the Intervention Programme. These resources were available on an online platform called ‘Sulis’ available to University of Limerick students only. Any student who attended one of the Intervention Programme tutorials had access to the Chemistry resources. Tests and quizzes, helpful websites, animations and a questions/discussion board were available for the students to use. In total, during the 10 week Intervention programme, 669 visits were made to the site. Figure 4.61 shows the popularity of the resources accessed by the students. As can be seen below, Tests and quizzes were the most used resource. This may have been due to the instant feedback feature of the resource. Students could test themselves on the weekly topics and see instantly how they performed.

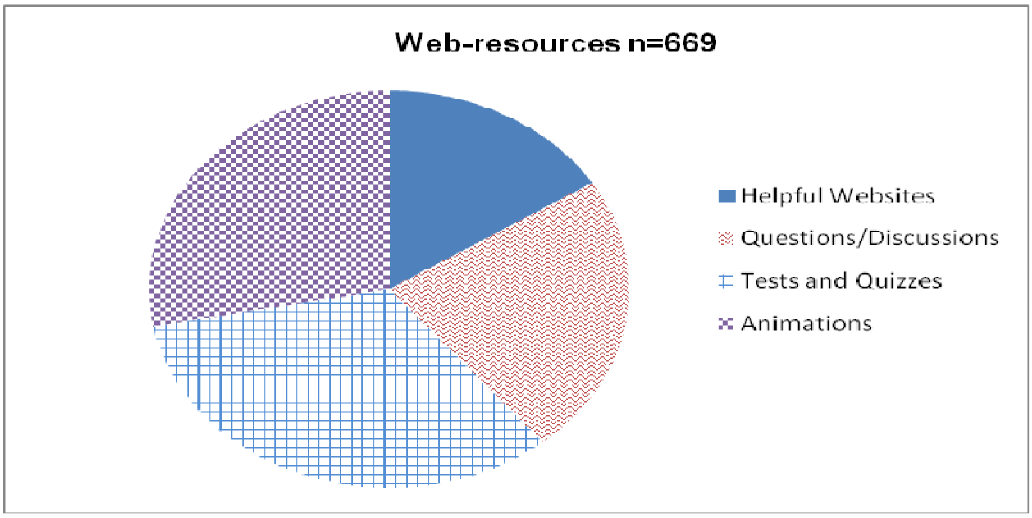


Figure 4.61 Usage of Web-Based Resources during Part 1

4.5.2 Part 2

Part 2 (n=9) focused on chemical calculations in particular the mole. A different pre- and post-diagnostic test was used for this part to test students’ ability to carry out chemical calculations.

4.5.2.1 Individual Questions in Pre- Diagnostic Test

Students completed a pre-diagnostic test on the first tutorial session of the Intervention Programme. Results of individual questions will be analysed in this section. Some questions that were used in the pre-diagnostic test were also used on the post-diagnostic test.

Question 1

Q1. What is the molar mass of oxalic acid $(COOH)_2$?

Figure 4.62 Question 1 in the Pre- and Post-Diagnostic Test.

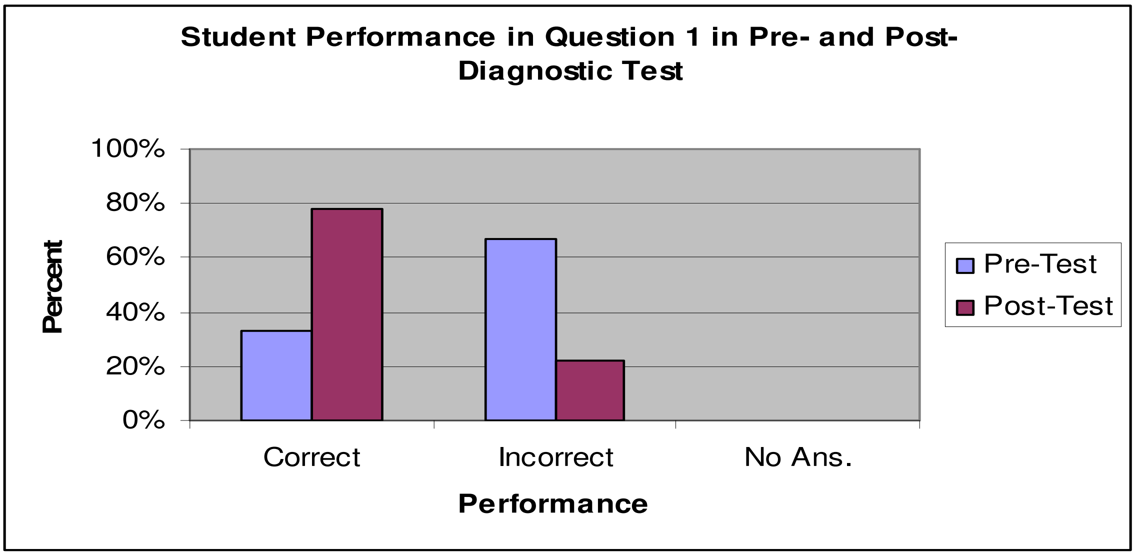


Figure 4.63 Performance of Students in Question 1 in the Pre- and Post Diagnostic Test.

This question asks the students to calculate the molar mass of oxalic acid. To answer this question successfully students need to be familiar with the molar mass of each atom and take into account the numbers of each that are present. This question appeared in both the pre-test and the post-test. 3 (33%) of the students got this question correct in the pre-test, this increased to 7 (78%) in the post-test. 6 (67%) of the students got this question incorrect in the pre-test, 2 (22%) got it incorrect in the post-test. All students answered this question in both the pre- and post-test.

Question 2

Q2. What is the molar mass of acetic acid (CH_3CO_2H)?

Figure 4.64 Question 2 in the Pre-Diagnostic Test.

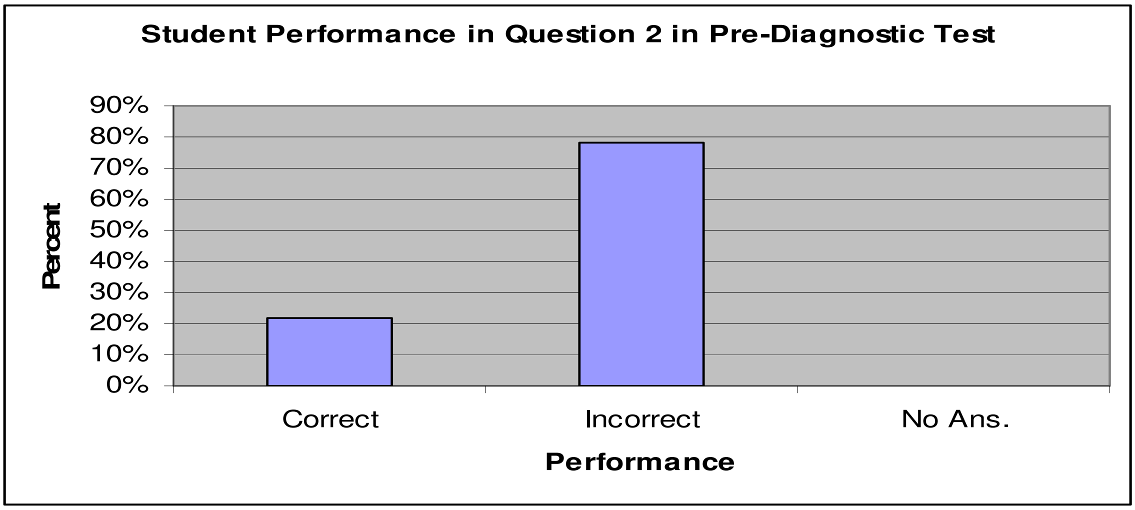


Figure 4.65 Performance of Students in Question 2 in the Pre-Diagnostic Test.

This question asks the students to calculate the molar mass of acetic acid. To answer this question successfully students need to be familiar with the molar mass of each atom and take into account the numbers of each that are present. 2 (22%) of the students got this question correct in the pre-test, 7 (78%) of the students got this question incorrect. All students answered this question in the pre-test.

Question 3

Q3. How many moles of acetic acid are there in a 10.0g sample?

Figure 4.66 Question 3 in the Pre-Diagnostic Test.

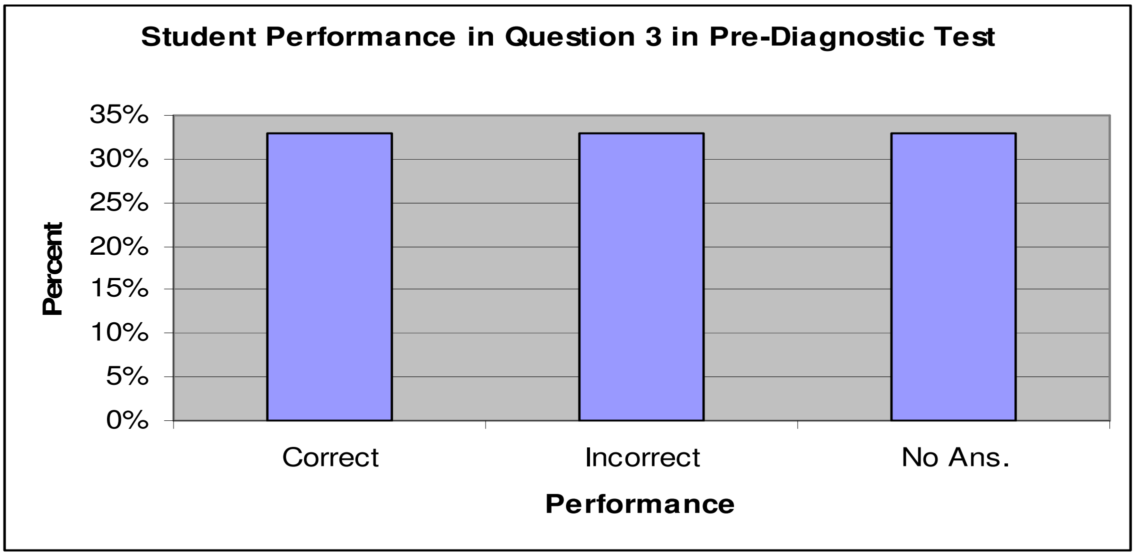


Figure 4.67 Performance of Students in Question 3 in the Pre-Diagnostic Test.

This question asks students to calculate how many moles of acetic acid are present in 10.0g. To answer this question correctly students need the molecular formula of acetic acid, which they can get from Question 2 in the test and also need to be familiar with converting mass to number of moles. 3 (33%) of the students got this question correct, 3 (33%) got it incorrect and 3 (33%) of the students didn't answer this question.

Question 4

Q4. To produce 1 litre of a 0.15M solution of oxalic acid, what mass of acid do we need?

Figure 4.68 Question 4 on the Pre- and Post Diagnostic Test.

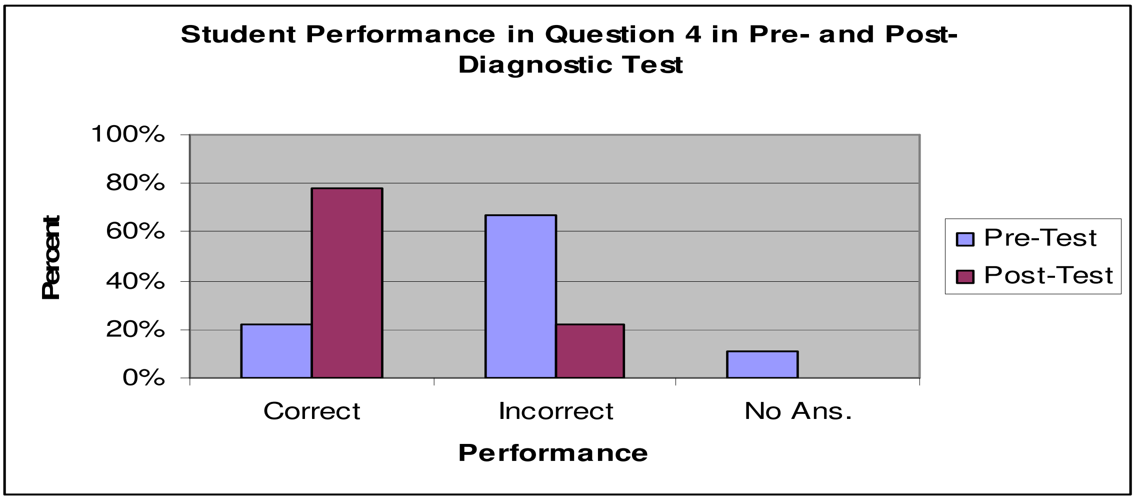


Figure 4.69 Performance of Students in Question 4 in the Pre- and Post-Diagnostic Test.

This question asks students to calculate how much oxalic acid is needed to make up a 0.15M solution. In order to successfully answer this question, students needed to be familiar with what molarity is and what it means. This question was used in both the Pre- and the Post-Diagnostic Tests. In the pre-test, 2 (22%) of the students got the question correct, this increased to 7 (78%) in the post-test. 6 (67%) of the students got this question incorrect in the pre-test and 2 (22%) got it incorrect in the post-test. 1 (11%) chose not to answer this question in the pre-test, all students attempted this question in the post-test.

Question 5

Q5. How many atoms are there in 34.0g of Carbon?

Figure 4.70 Question 5 in the Pre-Diagnostic Test.

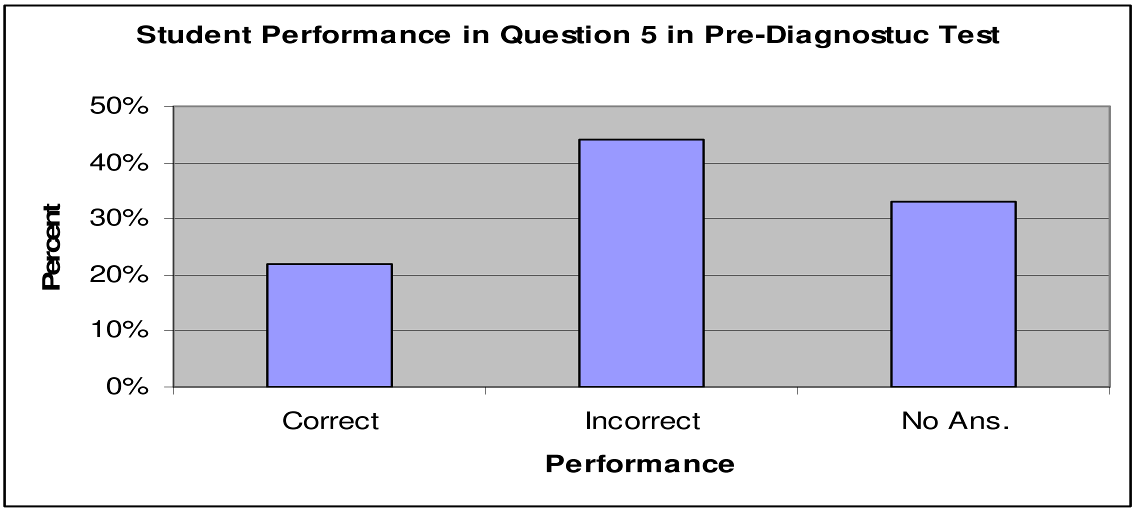
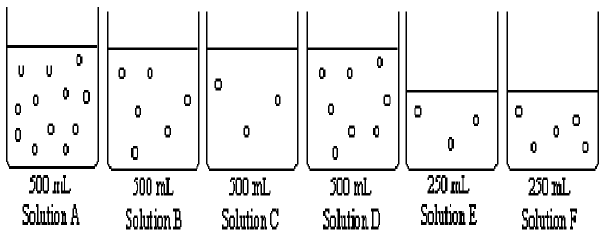


Figure 4.71 Performance of Students in Question 5 in the Pre-Diagnostic Test.

This question tests students' ability to calculate the amount of atoms present in a certain mass of Carbon. In order to complete this question students had to be familiar with Avogadro's number and molar mass. 2 (22%) of the students got the question correct in the pre-test, 4 (44%) got it incorrect and 3 (33%) of the students did not attempt this question in the pre-test.

Question 6

Q6. The drawings below represent beakers of aqueous solutions.



Answer the following questions.
Put A, B, C, D, E or F in the spaces provided:

Figure 4.72 Question 6 on the Pre- and Post-Diagnostic Test.

a) Which solution is most concentrated? Solution ____

Figure 4.73 Part A of Question 6 in the Pre- and Post-Diagnostic Test.

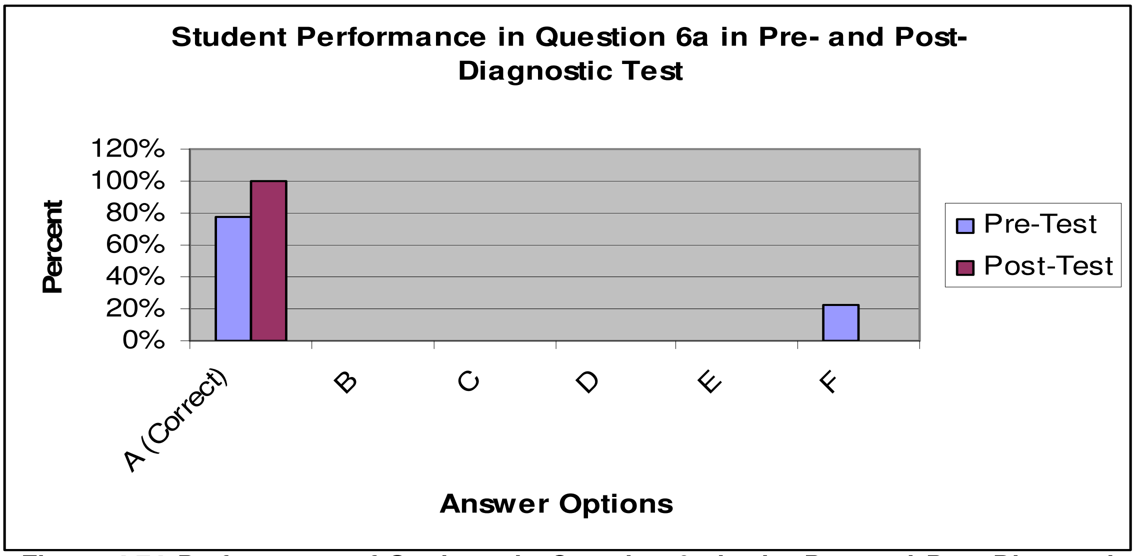


Figure 4.74 Performance of Students in Question 6a in the Pre- and Post-Diagnostic Test.

This question asked students to choose which solution was most concentrated. To do this question students needed to fully understand the meaning of 'concentrated'. This question was used on both the pre- and post-diagnostic test. In the pre-test, 7 (78%) of the students chose the correct option of A, this increased to 9 (100%) choosing that option in the post-test. 2 (22%) of the students got this question incorrect in the pre-test choosing option F.

b) Which solution is least concentrated? Solution _____

Figure 4.75 Part B of Question 6 in the Pre- and Post-Diagnostic Test.

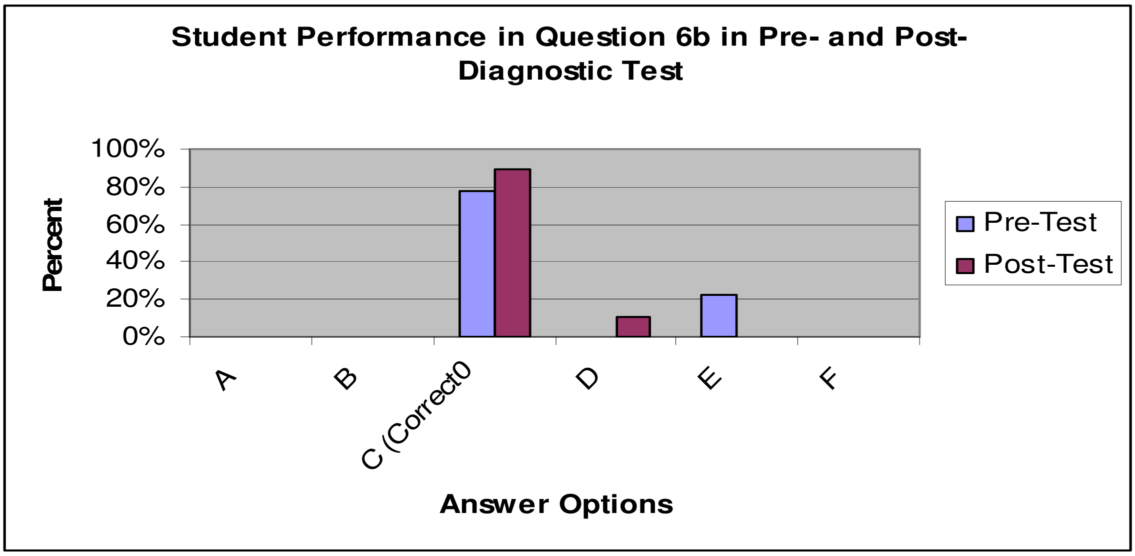


Figure 4.76 Performance of Students in Question 6 b in the Pre- and Post-Diagnostic Test.

This question asked students to choose which solution was least concentrated. To do this question students needed to understand the meaning of ‘concentrated’. This question was used on both the pre- and post-diagnostic test. In the pre-test, 7 (78%) of the students chose the correct option of C, this increased to 8 (89%) choosing that option in the post-test. 2 (22%) of the students got this question incorrect in the pre-test choosing option E and 1 (11%) chose the incorrect option of D in the post-test.

c) Which two solutions have the same concentration? Solution __and _?

Figure 4.77 Part C of Question 6 in the Pre- and Post-Diagnostic Test.

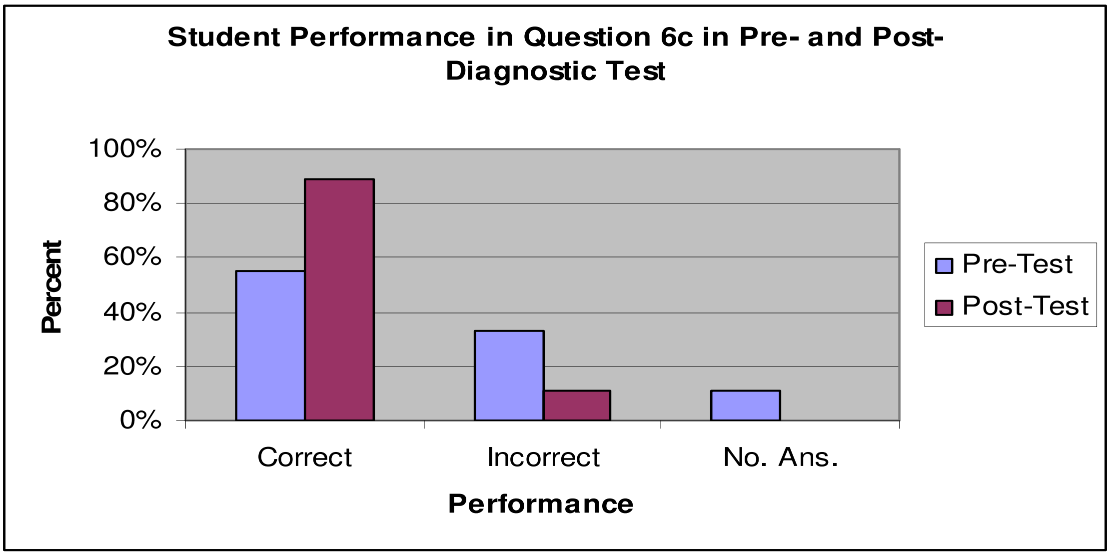


Figure 4.78 Performance of Students in Question 6c in the Pre- and Post-Diagnostic Test.

This question asks students to determine which 2 solutions had the same concentration. 5 (55%) of the students got this question correct in the pre-test, this increased to 8 (89%) in the post-test. 3 (33%) of the students got this question incorrect in the pre-test and 1 (11%) got it incorrect in the pre-test. 1 (11%) did not answer this question in the pre-test, but all students attempted this question in the post-test.

d) When Solutions E and F are combined, the resulting solution has the same concentration as Solution ___

Figure 4.79 Part D of Question 6 in the Pre- and Post-Diagnostic Test.

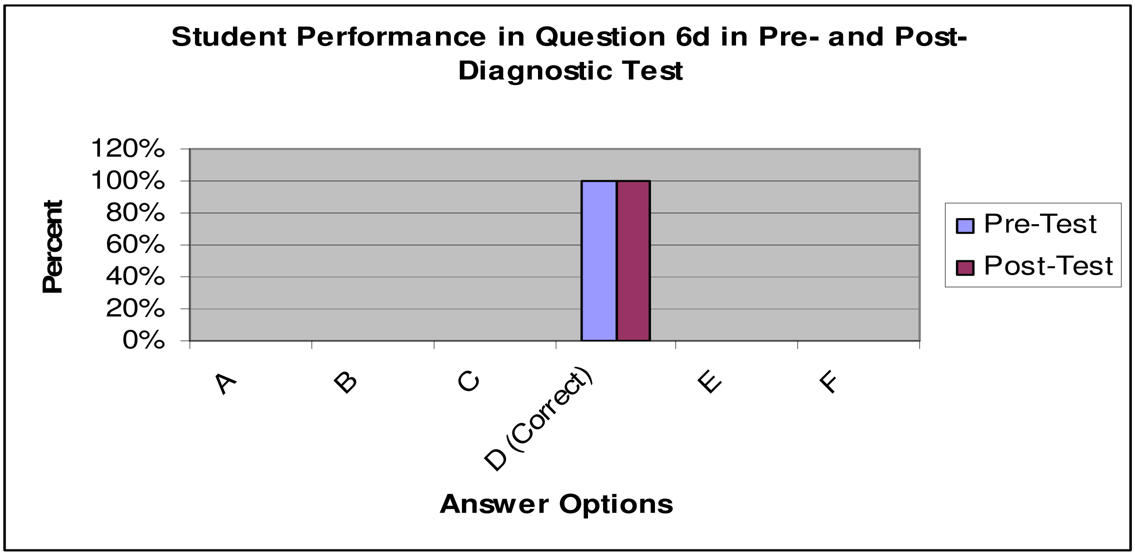


Figure 4.80 Performance of Students in Question 6d in the Pre- and Post-Diagnostic Test.

This question asked students to determine which solution has the same concentration of solution E and F combined. 9 (100%) of the students got this question correct in both the pre- and post-test.

e) If you evaporate off half of the water in Solution B, the resulting solution has the same concentration as Solution _____.

Figure 4.81 Part E of Question 6 in the Pre- and Post-Diagnostic Test.

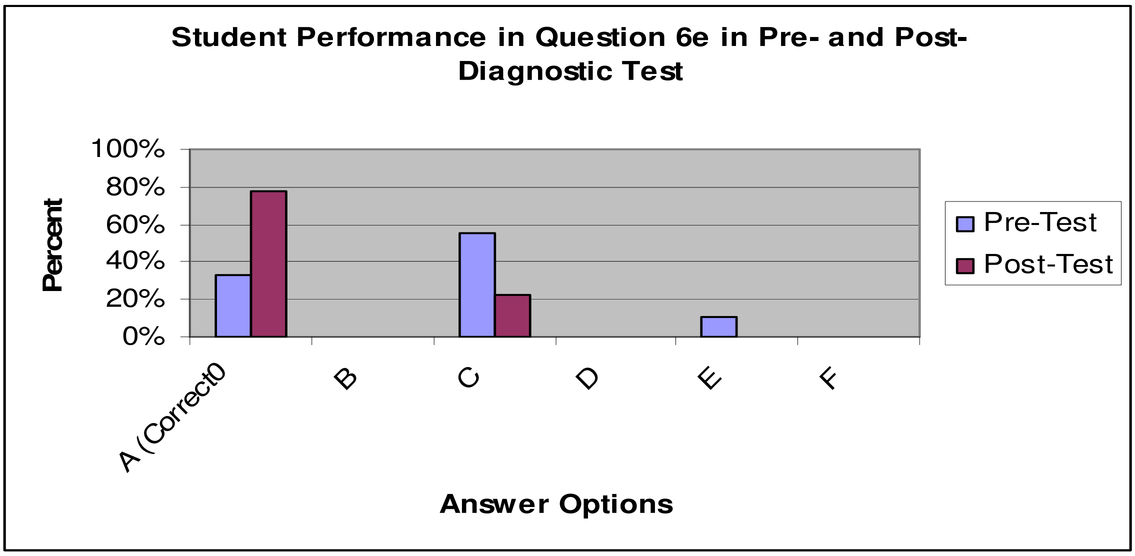


Figure 4.82 Performance of Students in Question 6e in the Pre- and Post-Diagnostic Test.

This question asks students if half the water was evaporated off from solution C, which solution would have the same concentration as it has. 3 (33%) of the students got this question correct in the pre-test choosing option A, this increased to 7 (78%) in the post-test. 5 (55%) of students got this question incorrect in the pre-test choosing option C and option E and 2 (22%) of the students got it incorrect in the post-test choosing option C.

Question 7

Q7. A compound containing only nitrogen and oxygen was found to contain 2.1g of nitrogen and 1.2g of oxygen. What is the mass percent composition of oxygen and nitrogen in this compound?

Figure 4.83 Question 7 on the Pre- and Post-Diagnostic Test.

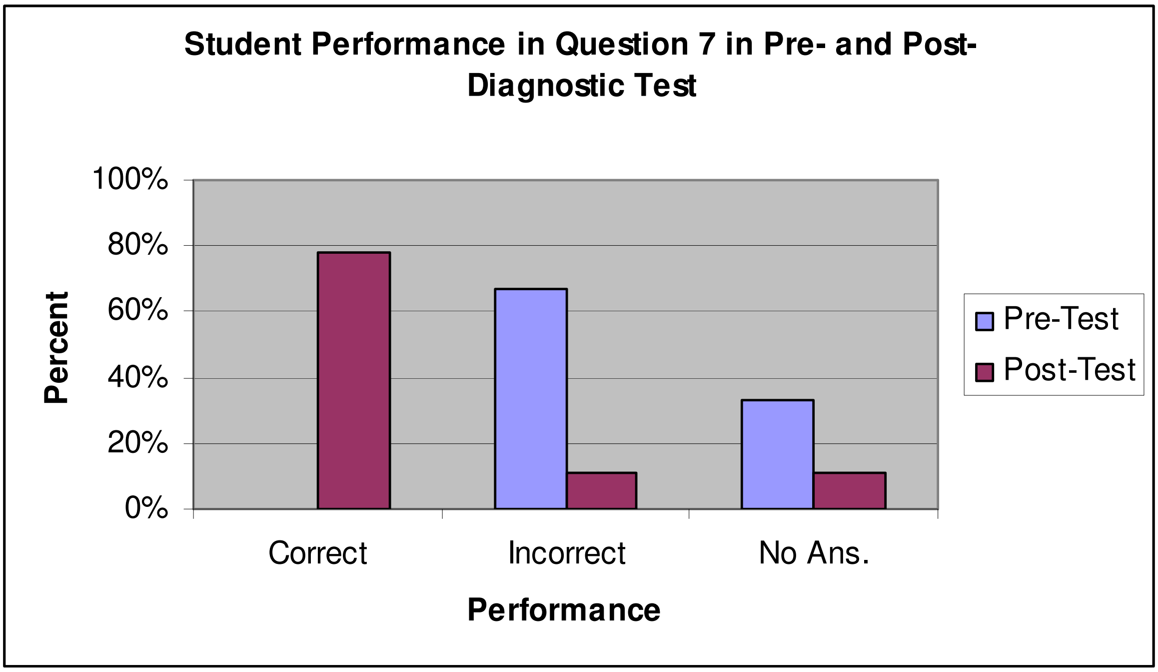


Figure 4.84 Performance of Students in Question 7 in the Pre- and Post-Diagnostic Test

This question asked students to calculate the mass percent composition of oxygen and nitrogen in a particular compound. This question was used in both the pre- and post-diagnostic test. None of the students got this question correct in the pre-test, 7 (78%) of the students answered it correctly in the post-test. 6 (67%) got this question incorrect in the pre-test, 1 (11%) got it incorrect in the pre-test. 3 (33%) of the students did not answer this question in the pre-test, 1 (11%) chose not to answer it in the post-test.

Question 8

Q8. Which is the correct mass percent composition of sodium nitrate, $NaNO_3$?

Figure 4.85 Question 8 in the Pre- and Post-Diagnostic Test.

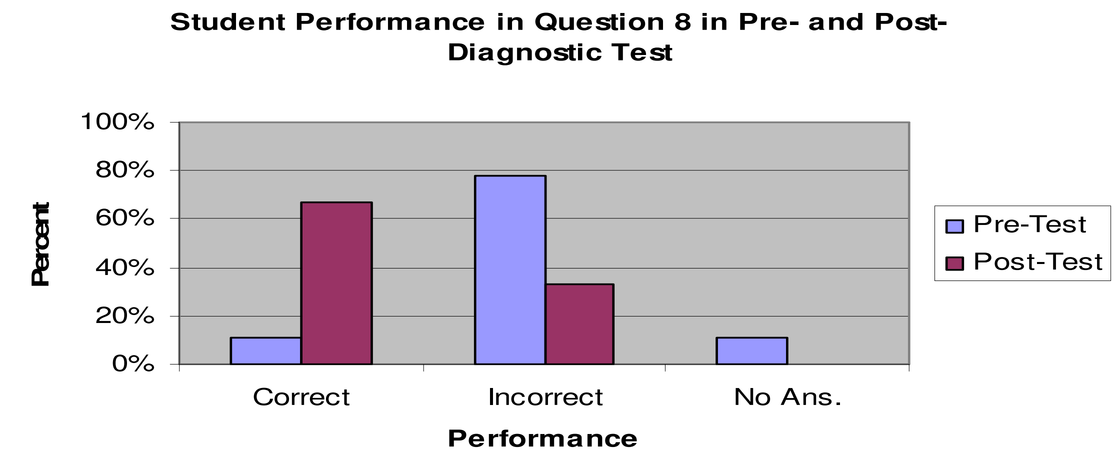


Figure 4.86 Performance of Students in Question 8 in the Pre- and Post-Diagnostic Test.

This question asked students to calculate the mass percent composition of a particular compound. This question was used in both the pre- and post-diagnostic test. 1 (11%) of the students completed this question correctly in the pre-test, and this increased to 6 (67%) getting it correct in the post-test. 7 (78%) of the students got it incorrect in the pre-test, 3 (33%) got it incorrect in the post-test. 1 (11%) did not answer this question in the pre-test and all students attempted this question in the post-test.

Question 9

Q9. 5.00g of calcium carbonate was dissolved in excess 0.150 M hydrochloric acid and dissolved according to the equation:

$$CaCO_{3(s)} + 2HCl_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O$$

Answer the following questions:

Figure 4.87 Question 9 in the Pre- and Post-Diagnostic Test.

a) How many moles of calcium carbonate were present in 5.00g $CaCO_{3(s)}$?

Figure 4.88 Part A of Question 9 in the Pre- and Post-Diagnostic Test.

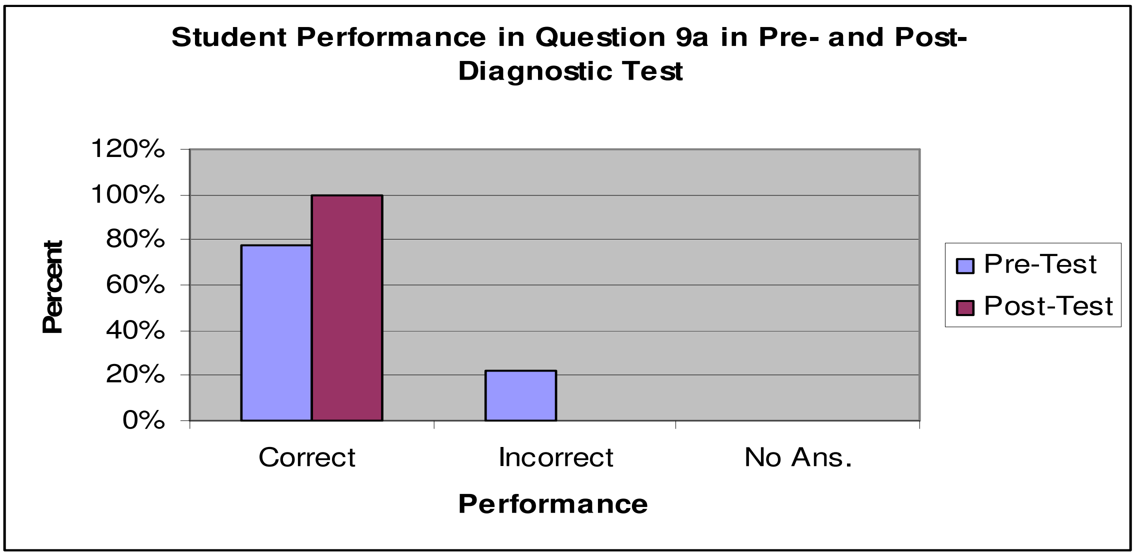


Figure 4.89 Performance of Students in Question 9a in the Pre- and Post-Diagnostic Test.

This question asked students to calculate the number of moles present in a certain mass of calcium carbonate. In order to successfully answer this question, students needed to be familiar with calculating the molecular mass of a compound and also how to use that information to figure out the number of moles present. This question was used in both the pre- and post-diagnostic test. 7 (78%) of the students completed this question correctly in the pre-test, and this increased to 9 (100%) getting it correct in the post-test. 2 (22%) of the students got it incorrect in the pre-test. All students attempted this question in the pre- and post-test.

b) What volume of 0.150 M HCl $_{(aq)}$ would be used up reacting with this mass of $CaCO_{3(s)}$?

Figure 4.90 Part B of Question 9 in the Pre- and Post-Diagnostic Test.

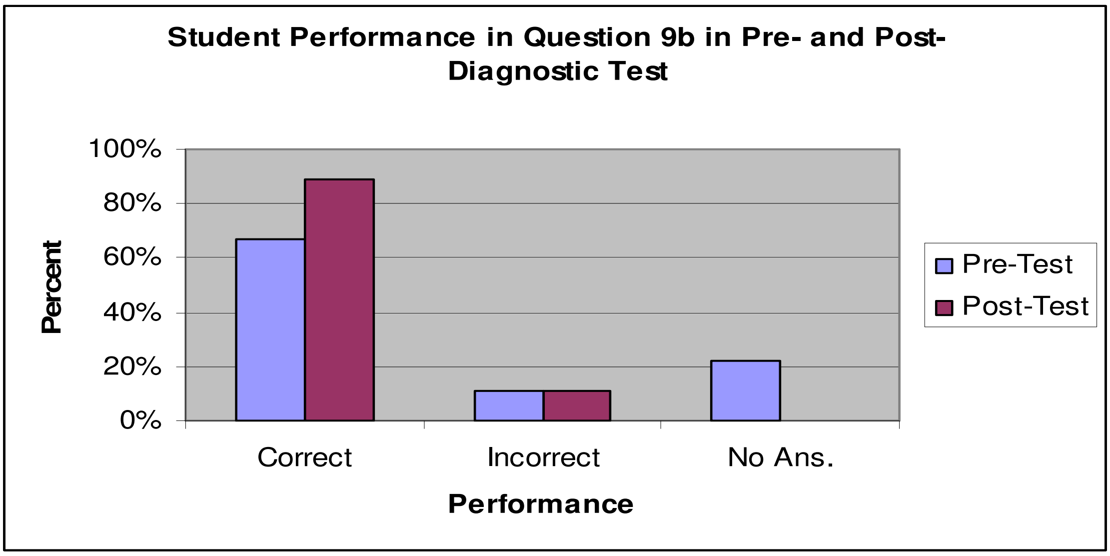


Figure 4.91 Performance of Students in Question 9B in the Pre- and Post-Diagnostic Test.

To answer this question correctly students needed to have a good understanding of stoichiometry. This question was used on both the pre- and post-diagnostic test. 6 (67%) of the students completed this question correctly in the pre-test, and this increased to 8 (89%) getting it correct in the post-test. 1 (11%) of the students got it incorrect in the pre-test, and 1 (11%) got it incorrect in the post-test. 2 (22%) did not answer this question in the pre-test and all students attempted this question in the post-test.

c) How many moles and what mass of $CaCl_2$ would be produced?

Figure 4.92 Part C of Question 9 in the Pre- and Post-Diagnostic Test.

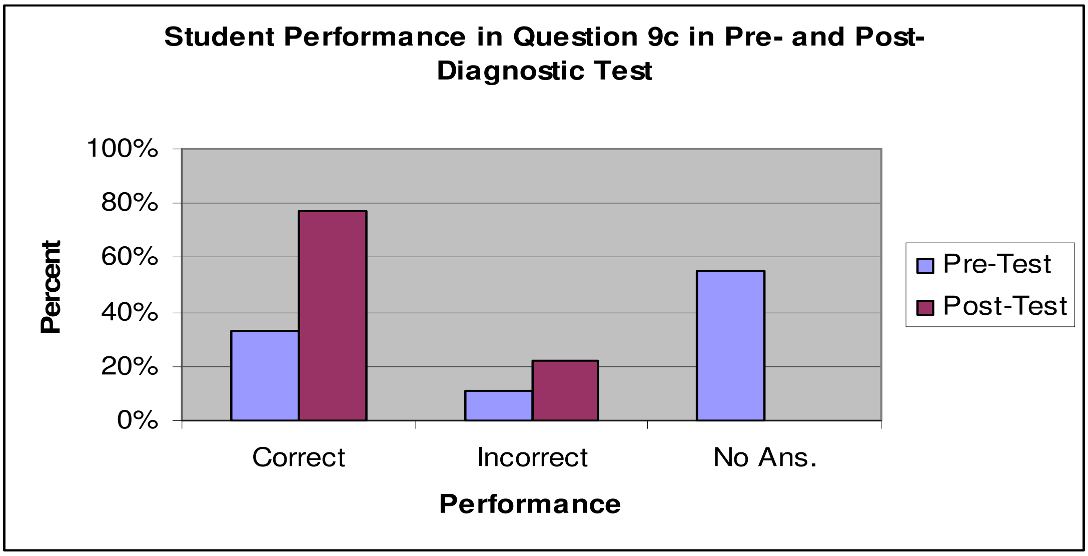


Figure 4.93 Performance of Students in Question 9c in the Pre- and Post-Diagnostic Test.

To answer this question correctly students needed to have a good understanding of stoichiometry and molarity. This question was used on both the pre- and post-diagnostic test. 3 (33%) of the students completed this question correctly in the pre-test, and this increased to 7 (78%) getting it correct in the post-test. 1 (11%) of the students got it incorrect in the pre-test, 2 (22%) got it incorrect in the post-test. 4 (44%) did not answer this question in the pre-test and all students attempted this question in the post-test.

d) What volume of $CO_{2(g)}$ would be produced at STP from the reaction of 5.00g of $CaCO_3$?

Figure 4.94 Part D of Question 9 in the Pre- and Post-Diagnostic Test.

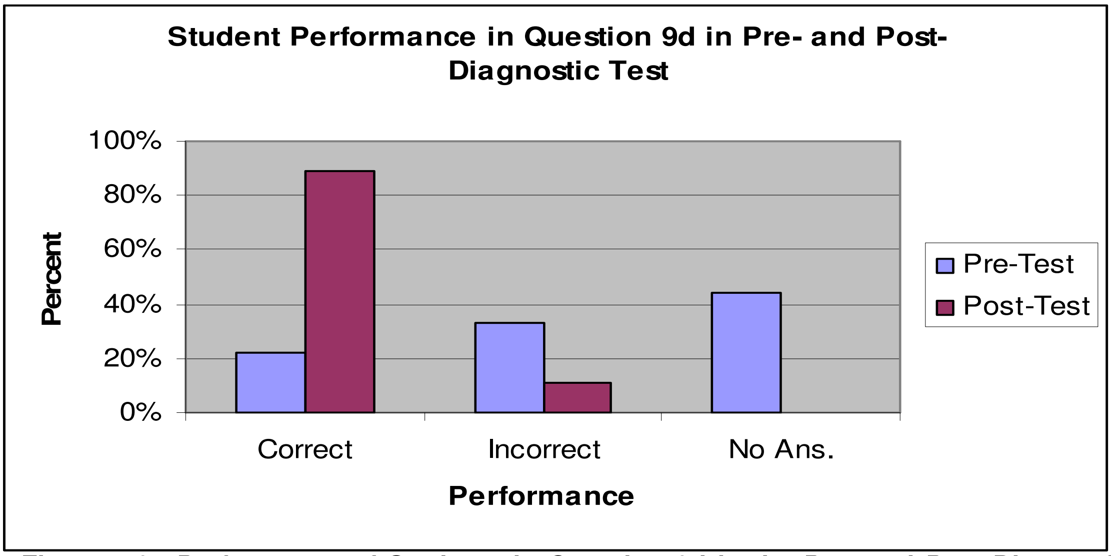


Figure 4.95 Performance of Students in Question 9d in the Pre- and Post-Diagnostic Test.

This question was used on both the pre- and post-diagnostic test. 2 (22%) of the students completed this question correctly in the pre-test, and this increased to 8 (89%) getting it correct in the post-test. 3 (33%) of the students got it incorrect in the pre-test, 1 (11%) got it incorrect in the post-test. 4 (44%) did not answer this question in the pre-test and all students attempted this question in the post-test.

<u>Question 10</u>

Q10. Ethene, C_2H_4 can be made from ethanol C_2H_5OH according to the following equation:

$$C_2H_5OH \rightarrow C_2H_4 + H_2O$$

Starting with 20g of ethanol, 8g of ethene was obtained. Calculate the percentage yield of ethene.

Figure 4.96 Question 10 in the Pre- and Post-Diagnostic Test.

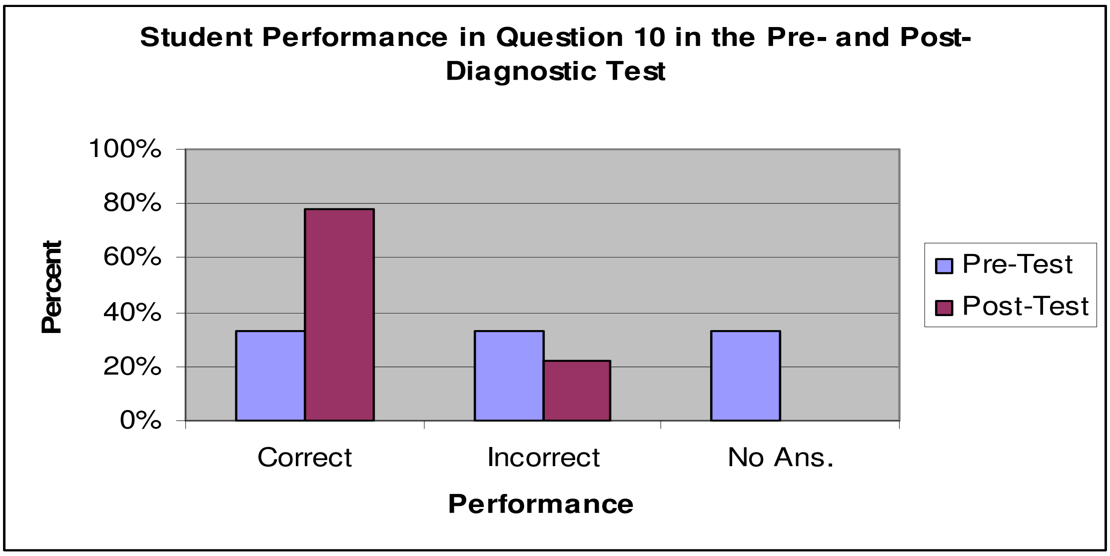


Figure 4.97 Performance of Students in Question 10 in the Pre- and Post-Diagnostic Test.

In order to complete this question students needed to be familiar with calculating the percentage yield and the relation between the formula, molar mass and mass. This question was used on both the pre- and post-diagnostic test. 3 (33%) of the students completed this question correctly in the pre-test, and this increased to 7 (78%) getting it correct in the post-test. 3 (33%) of the students got it incorrect in the pre-test, 2 (22%) got it incorrect in the post-test. 3 (33%) did not answer this question in the pre-test and all students attempted this question in the post-test.

. **Question 11**

Q11. 2.50g of iron (II) sulphate-7-water, $FeSO_4.7H_2O$, was dissolved in water and made up to 250 cm^3. Iron (II) sulphate reacts with sodium phosphate according to the equation: **$3Fe(II)SO_{4(aq)} + 2Na_3PO_{4(aq)} \rightarrow Fe_3^{(II)}(PO_4)_{2(s)} + 3Na_2SO_{4(aq)}$**

Figure 4.98 Question 11 in the Pre- and Post-Diagnostic Test.

a) Calculate the number of moles of iron (II) ions in the solution and hence the molarity of the solution.

Figure 4.99 Part A of Question 11 in the Pre- and Post-Diagnostic Test

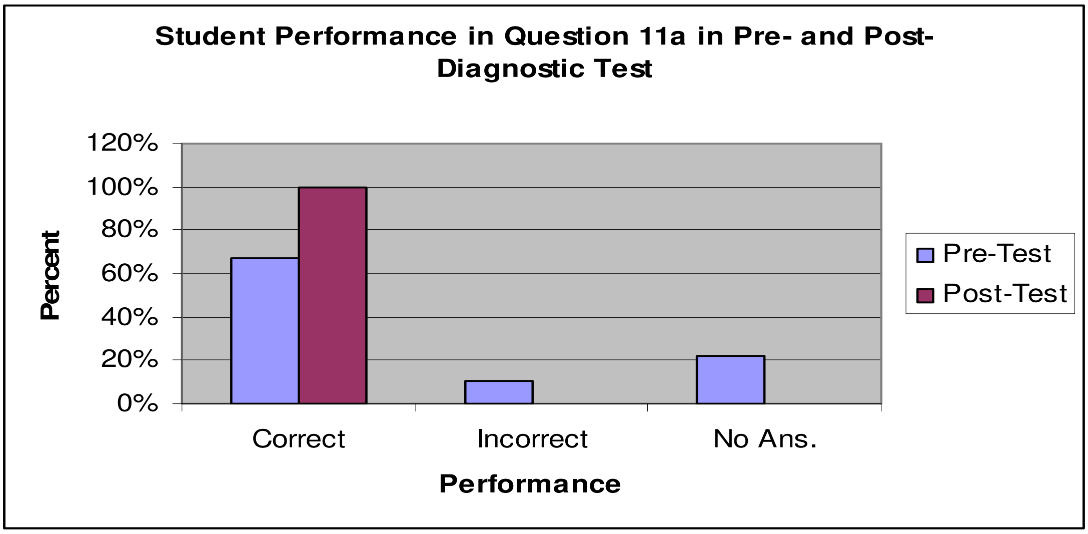


Figure 4.100 Performance of Students in Question 11a in the Pre- and Post-Diagnostic Test.

This question was used on both the pre- and post-diagnostic test. 6 (66%) of the students completed this question correctly in the pre-test, and this increased to 9 (100%) getting it correct in the post-test. 1 (11%) of the students got it incorrect in the pre-test. 2 (22%) did not answer this question in the pre-test and all students attempted this question in the post-test.

b) How many moles of sodium phosphate would be needed to react completely with all the iron$^{(II)}$ sulphate in the solution made above?

Figure 4.101 Part B of Question 11 in the Pre- and Post-Diagnostic Test.

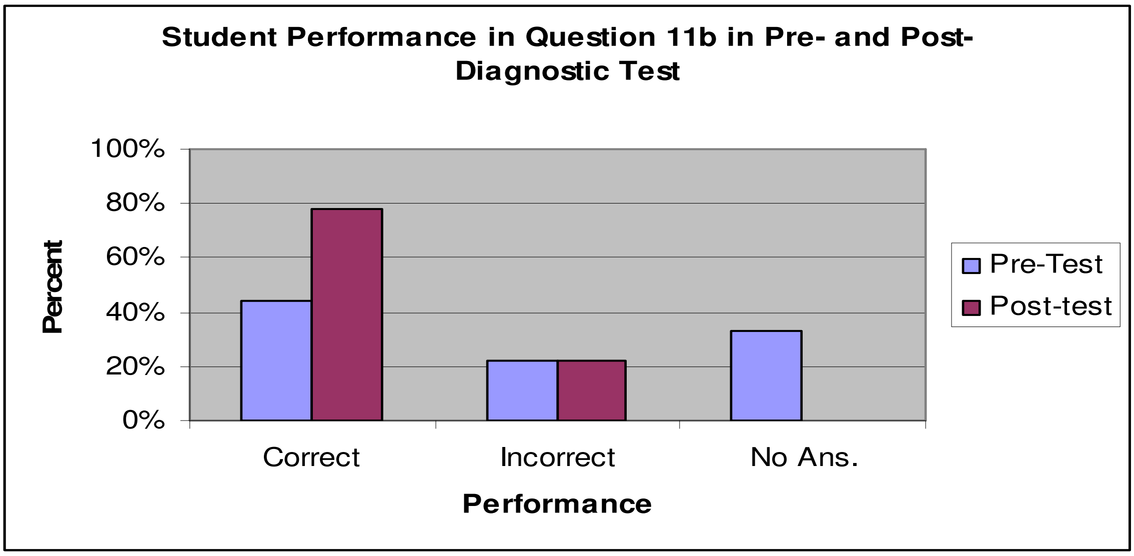


Figure 4.102 Performance of Students in Question 11b in the Pre- and Post-Diagnostic Test.

4 (44%) of the students completed this question correctly in the pre-test, and this increased to 7 (78%) getting it correct in the post-test. 2 (22%) of the students got it incorrect in the pre-test, 2 (22%) got it incorrect in the post-test. 3 (33%) did not answer this question in the pre-test and all students attempted this question in the post-test.

c) What volume of 0.100M sodium phosphate would be needed to react completely with all the iron$^{(II)}$ sulphate in the solution made above?

Figure 4.103 Part C of Question 11 in the Pre- and Post-Diagnostic Test.

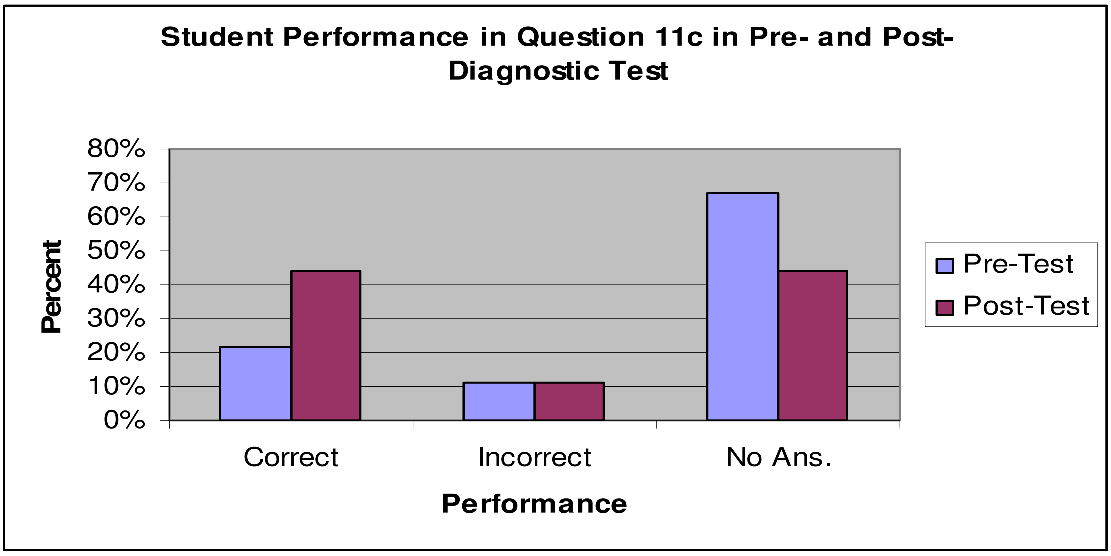


Figure 4.104 Performance of Students in Question 11c in the Pre- and Post-Diagnostic Test.

2 (22%) of the students completed this question correctly in the pre-test, this increased to 4 (44%) getting it correct in the post-test. 1 (11%) of the students got it incorrect in the pre-test, 1 (11%) got it incorrect in the post-test. 6 (67%) did not answer this question in the pre-test and 4 (44%) of students did not answer this question in the post-test.

d) What mass of $Fe_3^{(II)}(PO_4)_{2\,(s)}$ would be produced in the reaction above if all the iron$^{(II)}$ sulphate solution was reacted with excess sodium phosphate?

Figure 4.105 Part D of Question 11 in the Pre- and Post-Diagnostic Test.

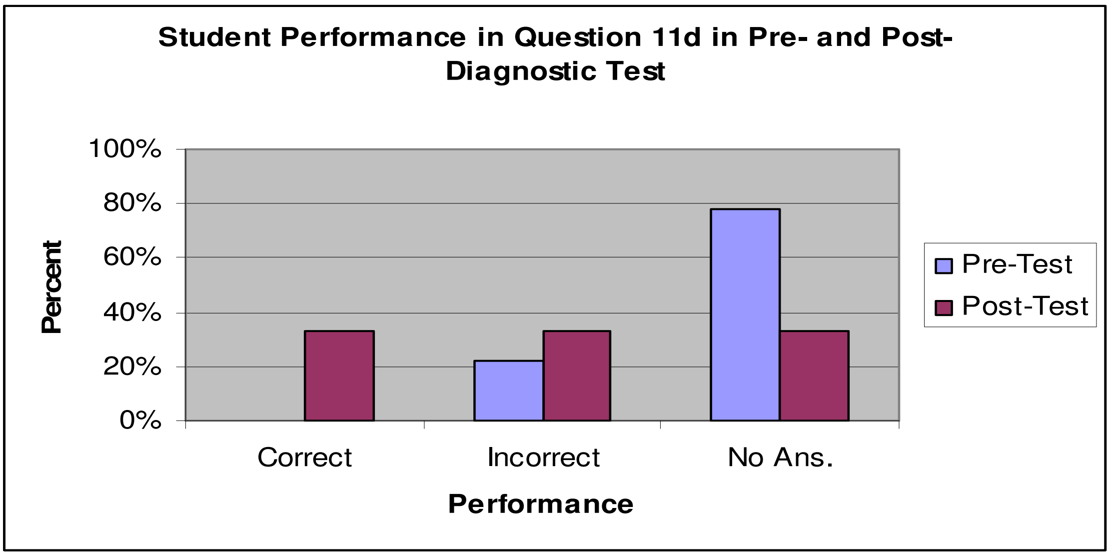


Figure 4.106 Performance of Students in Question 11d in the Pre- and Post-Diagnostic Test.

None of the students completed this question correctly in the pre-test, this increased to 3 (33%) getting it correct in the post-test. 2 (22%) of the students got it incorrect in the pre-test, but 3 (33%) got it incorrect in the post-test. 7 (78%) did not answer this question in the pre-test and 3 (33%) of students did not answer this question in the post-test.

4.5.2.2 Individual Questions in Post- Diagnostic Test

Students completed a post-diagnostic test on the last tutorial session of the Intervention Programme. This diagnostic test again sought to test students' understanding in general Chemistry concepts and ideas as in the pre-test. Results of individual questions will be analysed in this section. Some of the post-test questions have already been illustrated in Section 4.4.2.1 as they were included in both the pre- and post-diagnostic test.

Question 2

Q2. What is the molar mass of $Ca_3(PO_4)_2$?

Figure 4.107 Question 2 in the Post-Diagnostic Test.

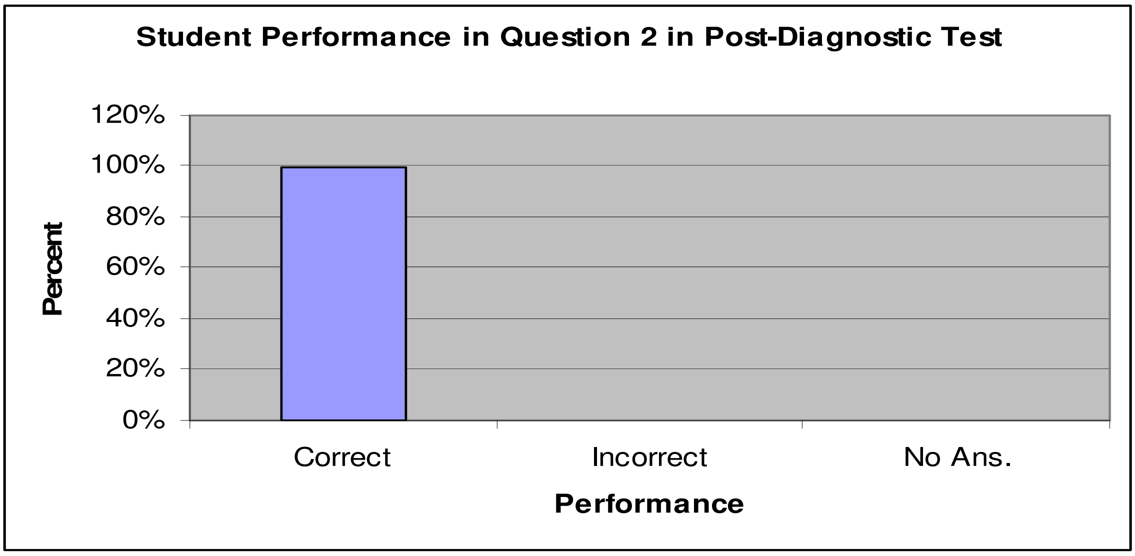


Figure 4.108 Performance of Students in Question 2 in the Post-Diagnostic Test.

This question asks the students to calculate the molar mass of $Ca_3(PO_4)_2$. To answer this question successfully students need to be familiar with the molar mass of each atom and take into account the numbers of each that are present. 9 (100%) of the students got this question correct.

Question 3

Q3. How many moles of sulfuric acid, H_2SO_4 are there in a 10.0g sample?

Figure 4.109 Question 3 in the Post-Diagnostic Test.

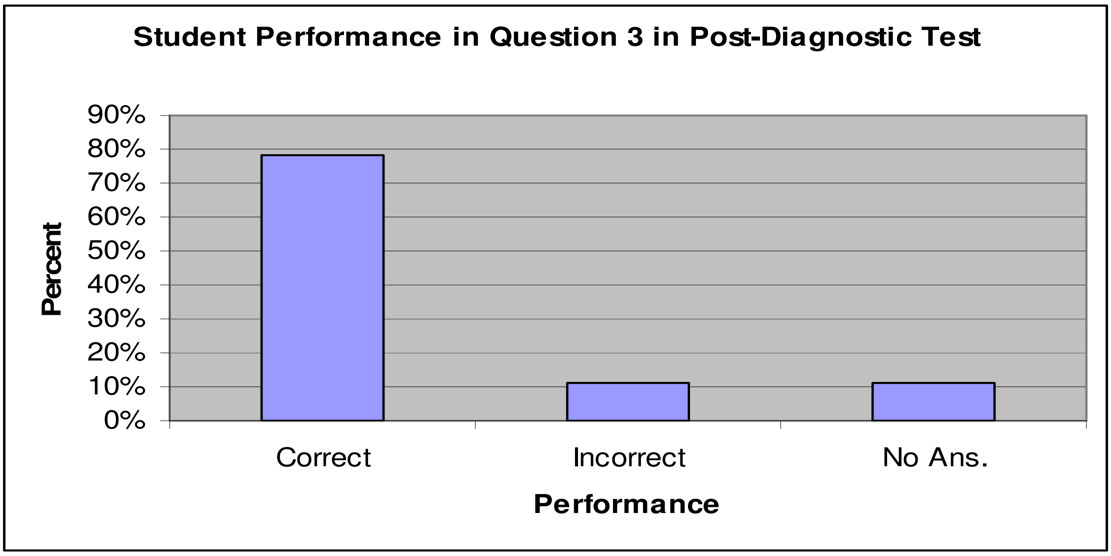


Figure 4.110 Performance of Students in Question 3 in the Post-Diagnostic Test.

This question asks students to calculate how many moles of sulfuric acid are present in 10.0g. To answer this question correctly students need to be familiar with converting mass to number of moles. 7 (78%) of the students got this question correct, 1 (11%) got it incorrect and 1(11%) of the students didn't answer this question.

Question 5

Q5. How many atoms are there in 117g of Water?

Figure 4.111 Question 5 in the Post-Diagnostic Test.

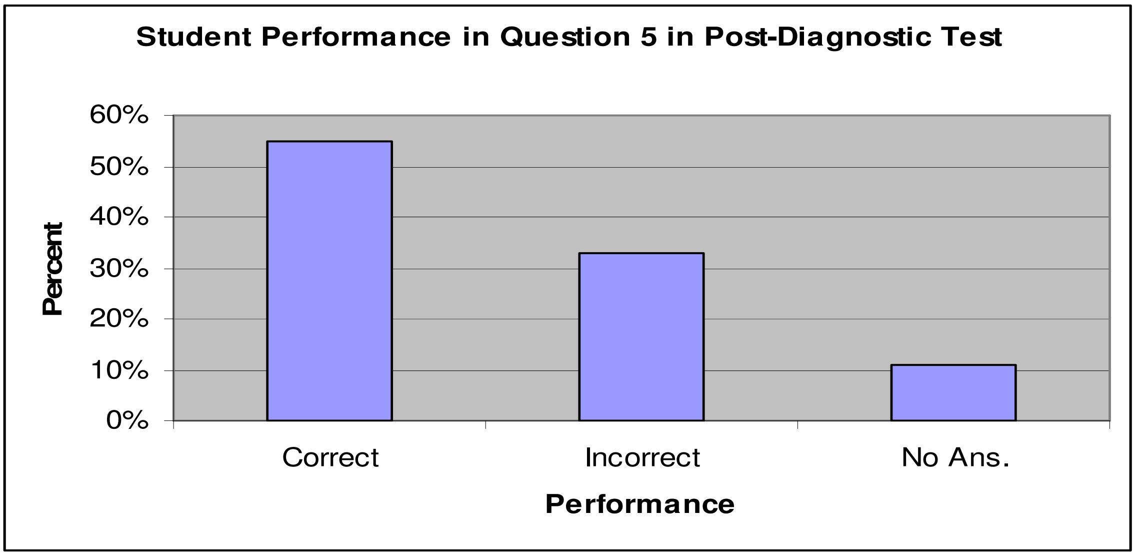


Figure 4.112 Performance of Students in Question 5 in the Post-Diagnostic Test.

This question tests students' ability to calculate the amount of atoms present in a certain mass of water. In order to complete this question students had to be familiar with Avogadro's number and the molar mass of water. 5 (56%) of the students got the question correct in the pre-test, 3 (33%) got it incorrect and 1 (11%) of the students did not attempt this question in the pre-test.

4.5.2.3 Overall Performance in Pre- and Post-Diagnostic Test

Students' performance in the pre- and post-diagnostic tests are shown in Figure 4.113.

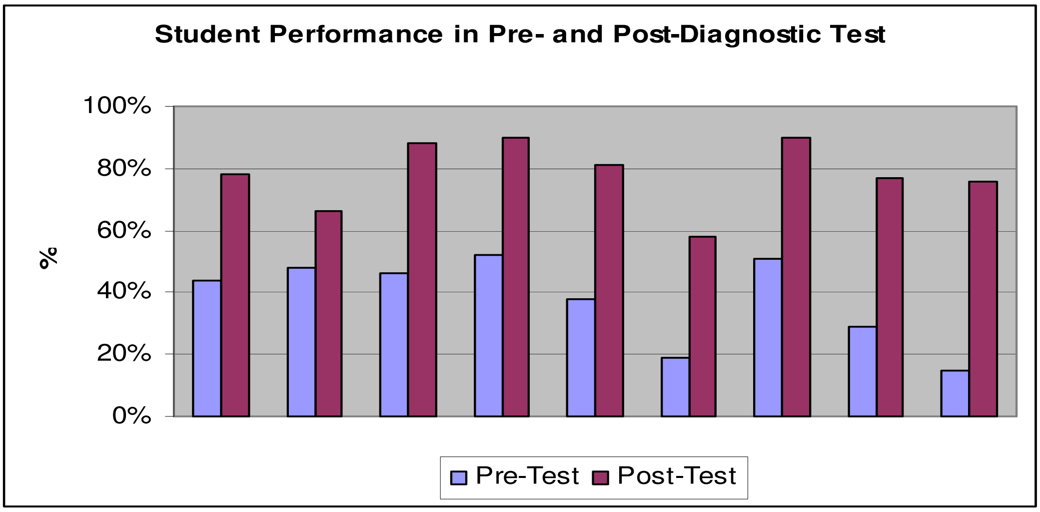


Figure 4.113 Performance of Students in the Pre- and Post-Diagnostic Test.

Participants in Group A experienced significantly higher results in the post-diagnostic test after taking part in the Intervention Programme (M=16.00, SE=2.08, p = 0.002) than in the pre-diagnostic test (M=7.66, SE=2.03). Participants in Group B also experienced significantly higher results in the post-diagnostic test after taking part in the programme (M=16.75, SE=1.11, p = 0.006) than in the pre-diagnostic test (M=10.00, SE=0.41). Participants in Group C also experienced higher results in the post-diagnostic test after taking part in the programme (M=16.00, SE=.0000, p = 0.083) than in the pre-diagnostic test (M=4.5, SE=1.50), but the increase was not significant.

4.5.2.4 Performance in Concurrent Chemistry Modules

During Phase 2, Part 2 of the Intervention Programme, both Group A and Group B were studying an 'Inorganic Chemistry' module and Group C were studying an 'Analytical Chemistry' module. The performance of students (who attended six or more of the Intervention Programme tutorials) in the written part of these examinations was analysed. In total 15 students were looked at. Not all of these students had completed a pre- or post-diagnostic test. As with Phase 1 and Phase 2, Part 1, the students who attended six or more tutorials during the Programme did slightly better in their concurrent Chemistry examination than students who did not participate.

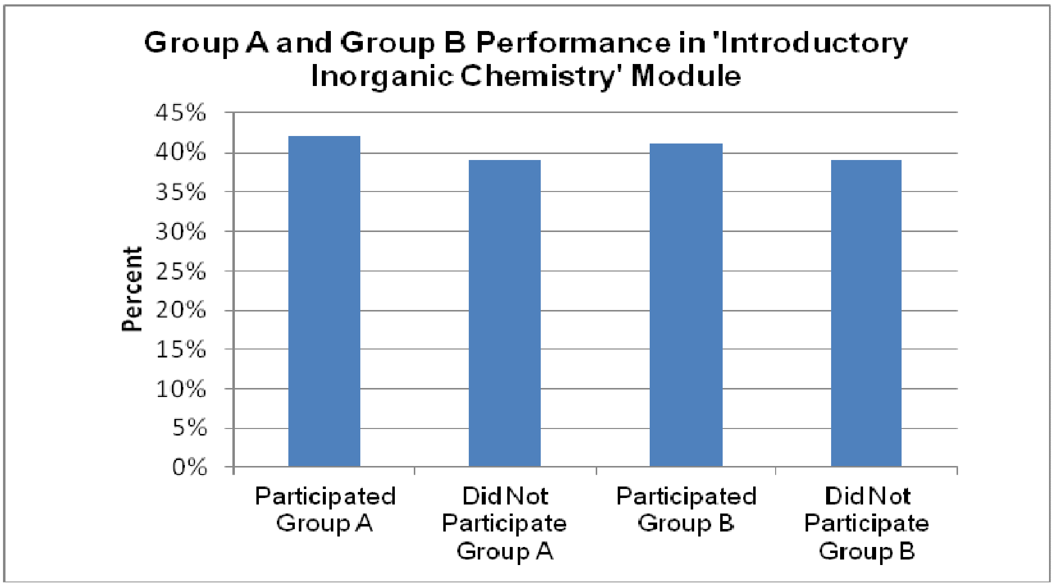


Figure 4.114 Performance of Group A and Group B in the concurrent Chemistry module

Group A experienced slightly higher grades (M =42.54, SE =2.46) than those who did not take part in the intervention programme (M =39.35, SE = 2.22). This difference was not significant p = 0.626. Group B experienced slightly better grades (M =40.63, SE =3.11) than those in the group who did not take part in the intervention programme (M = 39.14, SE =2.47). This difference was not significant p = 0.247; there was a small to medium size effect r =0.29.

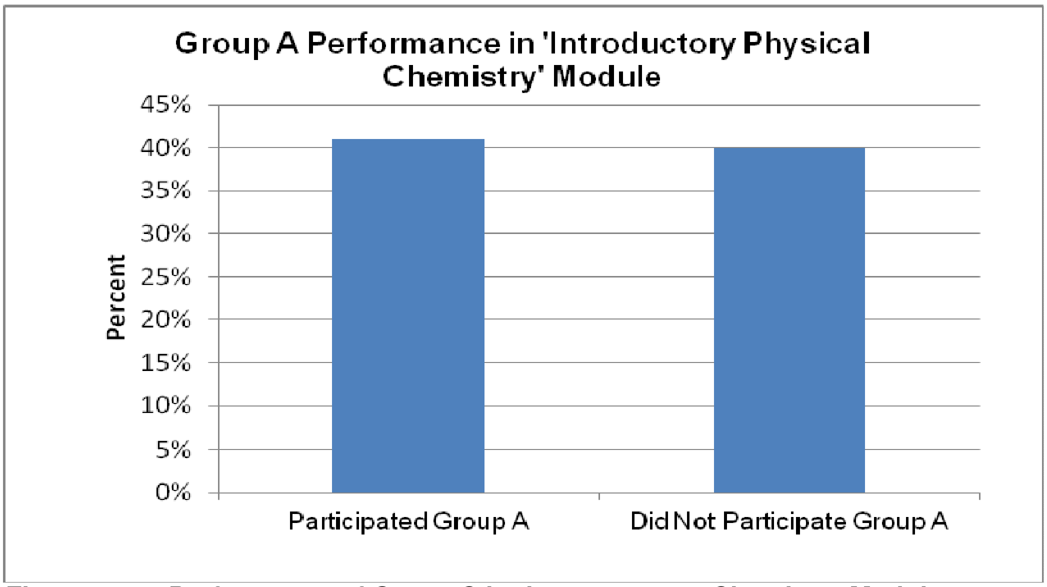


Figure 4.115 Performance of Group C in the concurrent Chemistry Module

Group C experienced slightly better grades (M =39.69, SE =2.49) than those in the group who did not take part in the intervention programme (M = 37.44, SE =2.87). This difference was significant p = 0.001.

4.5.2.5 Results from Attitude and Confidence Test

Results from the pre- and post-attitude and confidence tests will now be looked at. The same test was used to see if participation in the Intervention Programme had a positive influence on students' attitudes and confidence levels. As can be seen from Table 4.11 in the pre-attitude and confidence test, student's had 'Low' confidence level in 'Determining the appropriate units to use in a result', 'Tutoring another student in first year Chemistry course', 'Applying their knowledge of Chemistry to the real world', 'Understanding other areas of Science', 'Applying their knowledge of Chemistry to the real world' and also 'Succeeding in a Chemistry-related discipline'. Students had 'Average' confidence in 'Understanding key concepts of Chemistry', 'Choosing an appropriate formula to solve a problem', 'Approaching a Chemistry problem', 'Reading the procedure and carrying out an experiment without supervision' and 'Succeeding in their Chemistry courses'.

Table 4.11 Results of Pre-Attitude and Confidence Test for Phase 2-Part 2

	Mean	25th Percentile	**Median 50th Percentile**	75th Percentile	General Trend
Understand key concepts of Chemistry and explain topics in own words	1.43	2	**3**	3	Average Confidence
Choosing an appropriate formula to solve a Chemistry problem	1.65	2	**3**	3	Average Confidence
Approach a Chemistry problem in a systematic manner, working step by step	3.54	3	**3**	2	Average Confidence
Determine the appropriate units for a result determined using a formula	2.93	3	**2**	2	Low Confidence
Read the procedures for an experiment and conduct the experiment without supervision	3.81	3	**3**	3	Average Confidence
Tutor another student in a first year Chemistry course	2.85	3	**2**	3	Low Confidence
Apply your knowledge of Chemistry to the real world	1.75	2	**2**	2	Low Confidence

Understand other areas of Science	1.76	2	**2**	2	Low Confidence
Succeed in this Chemistry course	2.78	2	**3**	3	Average Confidence
Succeed in a Chemistry-related discipline	2.46	3	**2**	2	Low Confidence

Table 4.12 Results of Post-Attitude and Confidence Test for Phase 2-Part 2.

	Mean	25th Percentile	**Median 50th Percentile**	75th Percentile	General Trend
Understand key concepts of Chemistry and explain topics in own words	3.81	3	**4**	4	**High Confidence**
Choosing an appropriate formula to solve a Chemistry problem	2.36	2	**4**	4	**High Confidence**
Approach a Chemistry problem in a systematic manner, working step by step	3.48	3	**4**	4	**High Confidence**
Determine the appropriate units for a result determined using a formula	3.16	4	**3**	3	Average Confidence
Read the procedures for an experiment and conduct the experiment without supervision	3.79	4	**5**	4	**Very High Confidence**
Tutor another student in a first year Chemistry course	3.58	3	**4**	4	**High Confidence**
Apply your knowledge of Chemistry to the real world	2.63	2	**3**	3	Average Confidence
Understand other areas of Science	2.96	2	**3**	3	Average Confidence
Succeed in this Chemistry course	3.39	2	**4**	3	**High Confidence**
Succeed in a Chemistry-related discipline	2.94	3	**3**	3	Average Confidence

Table 4.12 shows the results of the post-attitude and confidence test, student's had 'Average' confidence level in 'Determining the appropriate units to use in a result', 'Applying their knowledge of Chemistry to the real world', 'Understanding other areas of Science' and also 'Succeeding in a Chemistry-related discipline'.Students had 'High' confidence in 'Understanding key concepts of Chemistry', 'Choosing an appropriate formula to solve a problem', 'Approaching a Chemistry problem', 'Tutoring another student in a first year Chemistry course' and 'Succeeding in their Chemistry courses'. Students had 'Very High' confidence level in 'Reading the procedure and carrying out an experiment without supervision'.

Table 4.13 Comparaison of pre- and post-attitude and Confidence Tests.

	Pre-Attitude and Confidence Test	*Post-Attitude and Confidence Test*
	General Trend	*General Trend*
Understand key concepts of Chemistry and explain topics in own words	Average Confidence	**High Confidence**
Choosing an appropriate formula to solve a Chemistry problem	Average Confidence	**High Confidence**
Approach a Chemistry problem in a systematic manner, working step by step	Average Confidence	**High Confidence**
Determine the appropriate units for a result determined using a formula	Low Confidence	Average Confidence
Read the procedures for an experiment and conduct the experiment without supervision	Average Confidence	**Very High Confidence**
Tutor another student in a first year Chemistry course	Low Confidence	**High Confidence**
Apply your knowledge of Chemistry to the real world	Low Confidence	Average Confidence
Understand other areas of Science	Low Confidence	Average Confidence
Succeed in this Chemistry course	Average Confidence	**High Confidence**
Succeed in a Chemistry-related discipline	Low Confidence	Average Confidence

From Table 4.13, it can be seen that after the Intervention Programme, students' attitudes and confidence levels increased in all of the ten statements.

4.5.2.6 Online Resources

Online resources were also made available during Part 2 of the Intervention Programme. These resources were available on an online platform called 'Sulis' available to University of Limerick students only. Any student who attended one of the Intervention Programme tutorials had access to the Chemistry resources. Tests and quizzes, helpful websites, animations and a questions/discussion board were available for the students to use. In total, during the 9 week Intervention programme, 406 visits were made to the site. Figure 4.106 shows the popularity of the resources accessed by the students.

As can be seen below, Tests and quizzes were the most used resource, similar to Part 1.

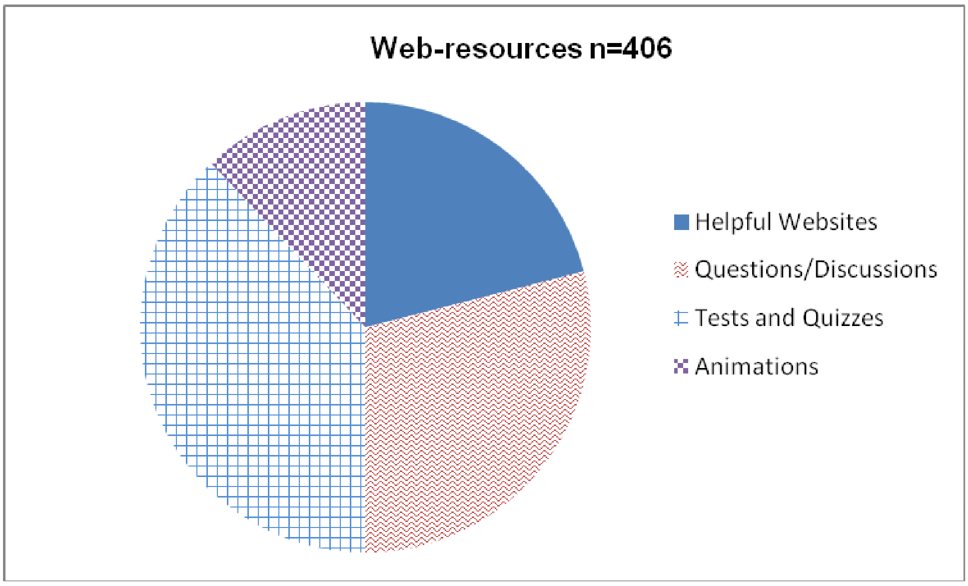


Figure 4.116 Usage of Web-Based Resources during Part 2

4.5.2.7 Interviews

The interviews (n=6) were semi-structured with a pre-prepared list of questions, which can be seen in the Appendix section.The interviews were carried out with six students (four males and two females) at the end of Phase 2. None of these students had experience of Chemistry at Leaving Certificate level, 50% (3) of the students were non-standard students and 50% (3) were standard students. Also, 33% (2) of the interviewed had studied higher level Mathematics for their Leaving certificates, 17% (1) had studied lower level Mathematics and the three non-standard students had some experience of Mathematics but it had been a number of years since they had studied the subject. The interviews provided an excellent insight into students' thoughts and opinions on Chemistry. They also gave an opportunity to investigate the thinking behind student's responses to questions on the diagnostic test. The main themes that emerged from an analysis of the student interviews were:

1. Language of Chemistry:

   Students find the language of Chemistry difficult to understand. 50% (3) of the interviewed students spoke about not fully understanding the vocabulary used in their Chemistry lectures and also on their Chemistry examination questions. This is a disadvantage in examination situations as they may know the particular method to correctly answer the question but because they cannot understand what the question is asking them to do, they cannot successfully complete the question.

'*There're lots of words that are similar, words that you wouldn't have heard of before and you don't really know what they mean. I never did Chemistry before so when you come in and they are talking about ions and cations and orbitals, all words that I didn't know, and I get mole and molarity mixed up*.' Student F

2. Chemical Calculations:

The mathematical element to Chemistry calculations was difficult for students also. This is no surprise as only two of the interviewed students had experience of higher level Mathematics. They spoke about having difficulty manipulating formulas and not knowing why they are doing certain steps in the calculations.

'*I don't understand the calculations, I just write down everything on the page that I know and hope some bit of it is right'*. Student E

3. Use of algorithms:

During the interviews, the students mentioned their reliance on algorithms. When probed further, students could not explain why the formulae gave them the right answer but despite that they used them to get the right answer by substituting in values. They had previously heard about deducing formulas from first principles but had never been shown how to do this correctly.

'I feel as though I am trying to learn a formula to do it without fully understanding it'. Student B

'If you get one thing wrong with your formula it affects all your answer and then all your answer is wrong'. Student F

4. Students also spoke about their attitudes towards Chemistry: four out of the six students interviewed said they liked and enjoyed Chemistry but found it the most difficult subject studied. The pace of the lectures was also mentioned and students thought that the amount of material covered in each

lecture slot was too much, especially if they had difficulty with the language used.

'*It's something I hadn't done and it's interesting but it has to be done so fast. Well I know that's the way with Universities, when you are coming in, things move kind of quick*' Student C

'If you miss one lecture, you are totally lost. So much gets done in an hour that you feel like you will never catch up'. Student A

5. 100% (6) of the students that were interviewed had a negative view on the practical aspect of their Chemistry courses. They did not see the link between the theory they do in their lectures and the practical work they do in the laboratory and thought it was a pointless aspect as they weren't benefiting from it. They admitted to making up the 'ideal' results to get a good mark on their laboratory reports.

4.6 Results from Phase 3

Phase 3 (n=18) was similar to Phase 1 and Part 1, already discussed, as it also focused on basic Chemistry concepts and ideas. It used the same pre- and post-diagnostic test as Phase 1 and Part 1.

4.6.1 Individual Answers from Pre- and Post-Diagnostic Test

As outlined above, the same diagnostic tests were used for Phase 3. As the questions from both the pre- and the post-diagnostic test are already outlined above in earlier sections, they will not be discussed in detail here. Instead, a table containing the results will be used.

Table 4.14 Performance in Individual Questions in Pre- and Post-Diagnostic Test Phase 3.

n=18	Pre-Diagnostic Test			Post-Diagnostic Test		
Question	Correct	Incorrect	No Ans.	Correct	Incorrect	No Ans.
1	5 (28%)	13 (73%)	0%	15 (83%)	3 (17%)	0%
2	5 (28%)	13 (72%)	0%	15 (83%)	3 (17%)	0%
3	4 (22%)	14 (78%)	0%	12 (67%)	6 (33%)	0%
4	4 (22%)	14 (78%)	0%	8 (44%)	10 (55%)	0%
5	7 (39%)	11 (61%)	0%	13 (72%)	5 (28%)	0%
6	1 (5%)	15 (83%)	2 (11%)	11 (61%)	7 (39%)	0%
7	3 (17%)	11 (61%)	4 (22%)	15 (83%)	2 (11%)	1 (5%)
8	2 (11%)	14 (78%)	2 (11%)	14 (78%)	3 (17%)	1 (5%)
9	8 (44%)	9 (50%)	1 (5%)	10 (55%)	3 (17%)	5 (28%)
10	2 (11%)	6 (33%0	10 (56%)	10 (55%)	3 (17%)	5 (28%)
11	2 (11%)	11 (61%)	5 (28%)	14 (78%)	4 (22%)	1 (5%)
12	3 (17%)	14 (78%)	1 (5%)	15 (83%)	2 (11%)	1 (5%)
13	2 (11%)	10 (55%)	6 (33%)	13 (72%)	3 (17%)	2 (11%)
14	3 (17%)	13 (72%)	2 (11%)	8 (44%)	9 (50%)	1 (5%)
15	14 (78%)	2 (11%)	2 (11%)	15 (83%)	3 (17%)	0%
16	6 (33%)	12 (67%)	0%	12 (67%)	6 (33%)	0%

4.6.2 Overall Performance in Pre- and Post-Diagnostic Test

The students' overall performance in the pre- and post-diagnostic tests are shown in Figure 4.107, where their percentage of correct answers is shown.

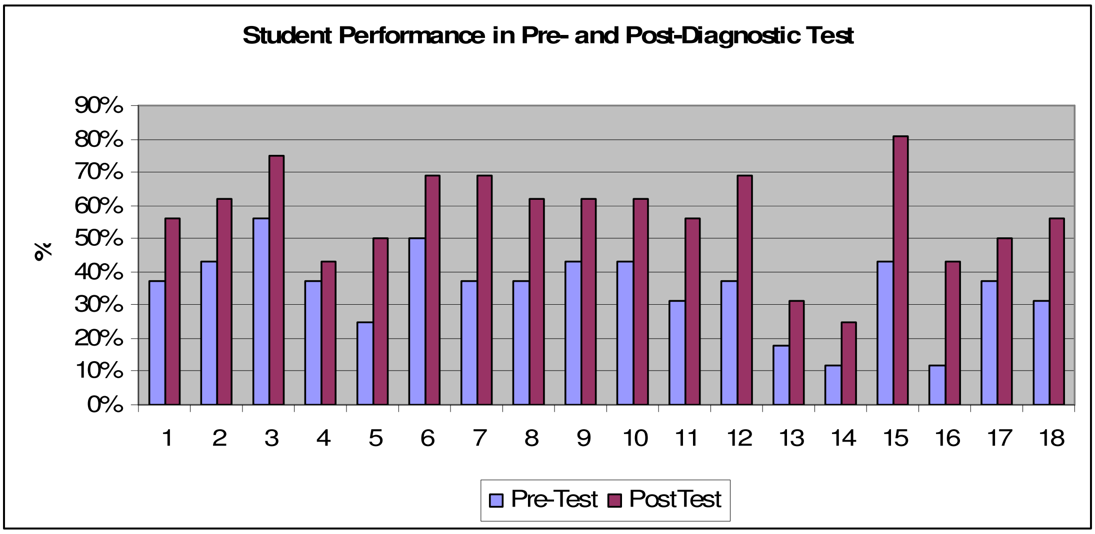


Figure 4.117 Performance of Students in the Pre- and Post-Diagnostic Test

Participants in group A experience significantly higher scores in the post-test after taking part in Phase 3 of the Intervention Programme (M=67.22, SE=2.12, p=0.000) than in the pre-test (M=39.88, SE=2.33). Participants in Group B experience higher scores in the post-test after taking part in the programme (M=46.66, SE=3.32, p=0.320) than in the pre-diagnostic test (M=41.27, SE=3.79), though this was not significant. Participants in Group C also experience higher scores in the post-test after taking part in the programme (M=49.65, SE=4.76, p=0.247) than in the pre-test (M=47.12, SE=2.54), though this was not significant.

4.6.3 Results from Concurrent Chemistry Module

During Phase 3 of the Intervention Programme, Group A were concurrently studying an 'Introductory Physical Chemistry' module and Group B and Group C were studying a 'General Chemistry 2' module. The performance of students (who attended six or more of the Intervention Programme tutorials) in the written part of these examinations was analysed. In total, 25 students were looked at. However, not all of these students had completed a pre-diagnostic test and only some had completed a post-diagnostic test.

On average, in the 'Inorganic Chemistry' module, students that attended six or more tutorials did better than their peers in the same course who did not attend.

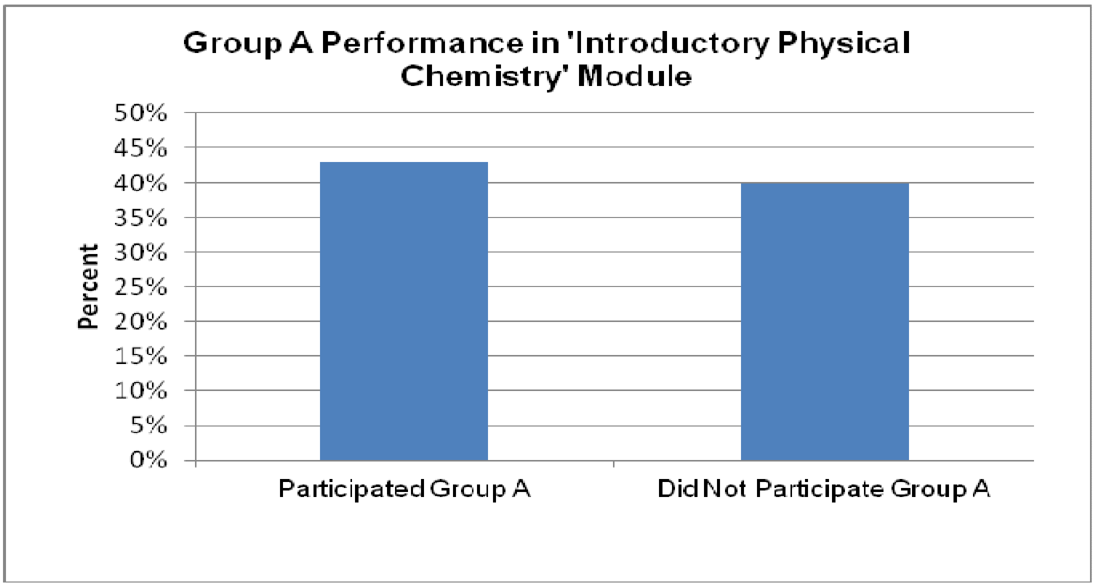


Figure 4.118 Performance of Group A in the concurrent Chemistry Module

Group A experienced slightly higher grades (M =42.99, SE =317) than those who did not take part in the intervention programme (M =40.11, SE = 3.79). This difference was not significant p = 0.626; however it did represent a small to medium size effect r = 0.27.

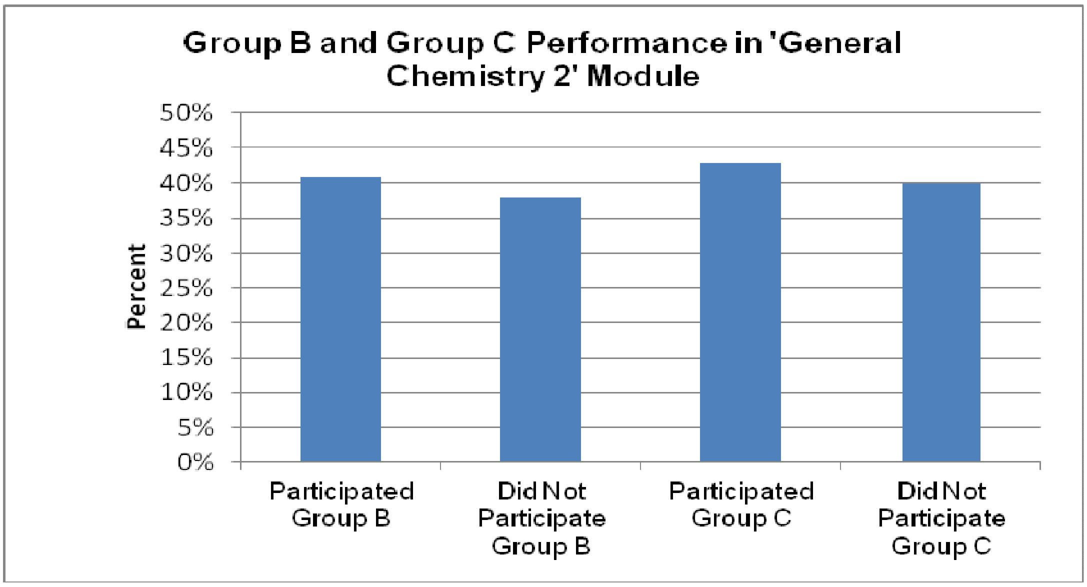


Figure 4.119 Performance of Group B and Group C in the concurrent Chemistry module

Group B experienced slightly better grades (M =42.13, SE =1.51) than those in the group who did not take part in the intervention programme (M = 38.14, SE =5.47). This difference was not significant p = 0.249. Group C experienced slightly better grades (M =43.35, SE =3.72) than those in the group who did not take part in the intervention programme (M = 40.16, SE =4.67). This difference was not significant p = 0.320.

4.6.4 Results from Attitude and Confidence Test

Results from the pre- and post-attitude and confidence tests will now be looked at. The same test was used to see if participation in the Intervention Programme had a positive influence on students' attitudes and confidence levels. As can be seen from table 4.15 in the pre-attitude and confidence test, student's had 'Very Low' confidence level in 'Choosing an appropriate formula to solve a problem' and 'Applying their knowledge of Chemistry to the real world'. Students had 'Low' confidence in 'Understanding key concepts of

Chemistry', 'Tutoring another student in first year Chemistry, 'Understanding other areas of Science', 'Succeeding in their Chemistry courses' and 'Succeeding in a Chemistry-related discipline'. Students had 'Average' confidence level in 'Approaching a Chemistry problem', 'Determining the appropriate units to use in a result', course' and. 'Reading the procedure and carrying out an experiment without supervision'.

Table 4.15 Results of Pre-Attitude and Confidence Test for Phase 3.

	Mean	25^{th} Percentile	**Median 50^{th} Percentile**	75^{th} Percentile	General Trend
Understand key concepts of Chemistry and explain topics in own words	2.61	2	**2**	2	Low Confidence
Choosing an appropriate formula to solve a Chemistry problem	2.36	2	**1**	2	Very Low Confidence
Approach a Chemistry problem in a systematic manner, working step by step	1.97	3	**3**	2	Average Confidence
Determine the appropriate units for a result determined using a formula	2.57	2	**3**	3	Average Confidence
Read the procedures for an experiment and conduct the experiment without supervision	2.79	3	**3**	3	Average Confidence
Tutor another student in a first year Chemistry course	3.11	3	**2**	2	Low Confidence
Apply your knowledge of Chemistry to the real world	2.67	2	**1**	2	Very Low Confidence
Understand other areas of Science	2.16	2	**2**	2	Low Confidence
Succeed in this Chemistry course	2.96	2	**2**	3	Low Confidence
Succeed in a Chemistry-related discipline	3.21	3	**2**	2	Low Confidence

Table 4.16 Results of Post-Attitude and Confidence Test for Phase 3.

	Mean	25th Percentile	**Median 50th Percentile**	75th Percentile	General Trend
Understand key concepts of Chemistry and explain topics in own words	3.56	3	**4**	3	**High Confidence**
Choosing an appropriate formula to solve a Chemistry problem	2.43	2	**3**	2	Average Confidence
Approach a Chemistry problem in a systematic manner, working step by step	3.96	3	**4**	3	**High Confidence**
Determine the appropriate units for a result determined using a formula	2.79	4	**4**	3	**High Confidence**
Read the procedures for an experiment and conduct the experiment without supervision	3.64	4	**5**	4	**Very High Confidence**
Tutor another student in a first year Chemistry course	3.46	3	**4**	4	**High Confidence**
Apply your knowledge of Chemistry to the real world	3.15	2	**3**	3	Average Confidence
Understand other areas of Science	2.72	2	**3**	2	Average Confidence
Succeed in this Chemistry course	3.71	2	**4**	3	**High Confidence**
Succeed in a Chemistry-related discipline	2.14	3	**3**	2	Average Confidence

Table 4.16 shows the results of the post-attitude and confidence test, student's had 'Very high' confidence level in 'Reading the procedure and carrying out an experiment without supervision'. Students had 'high' confidence level in 'Understanding key concepts of Chemistry', 'Approaching a Chemistry problem', 'Determining the appropriate units to use in a result', 'Tutoring another student in first year Chemistry course' and 'Succeeding in their Chemistry courses'. Students had 'average' confidence in 'Choosing an appropriate formula to solve a problem', 'Applying their knowledge of Chemistry to the real world', 'Understanding other areas of Science' and 'Succeeding in a Chemistry-related discipline'.

Table 4.17 Comparison of pre- and post-attitude and Confidence Tests.

	Pre-Attitude and Confidence Test	*Post-Attitude and Confidence Test*
	General Trend	*General Trend*
Understand key concepts of Chemistry and explain topics in own words	Low Confidence	**High Confidence**
Choosing an appropriate formula to solve a Chemistry problem	Very Low Confidence	Average Confidence
Approach a Chemistry problem in a systematic manner, working step by step	Average Confidence	**High Confidence**
Determine the appropriate units for a result determined using a formula	Average Confidence	**High Confidence**
Read the procedures for an experiment and conduct the experiment without supervision	Average Confidence	**Very High Confidence**
Tutor another student in a first year Chemistry course	Low Confidence	**High Confidence**
Apply your knowledge of Chemistry to the real world	Very Low Confidence	Average Confidence
Understand other areas of Science	Low Confidence	Average Confidence
Succeed in this Chemistry course	Low Confidence	**High Confidence**
Succeed in a Chemistry-related discipline	Low Confidence	Average Confidence

From Table 4.17, it can be seen that after the Intervention Programme, students' attitudes and confidence increased in all of the ten statements.

4.6.5 Online Resources

Online resources were also made available during Phase 3 of the Intervention Programme. Similarly to Part 1 and Part 2, these resources were available on an online platform called 'Sulis' available to University of Limerick students only. Any student who attended one of the Intervention Programme tutorials had access to the Chemistry resources. Tests and quizzes, helpful websites, animations and a questions/discussion board were available for the students to use. In total, during the 10 week Intervention programme, 568 visits were made to the site. Figure 4.110 shows the popularity of the resources accessed by the students. As can be seen below, Tests and quizzes were the most used resource, similar to Part 1 and 2. This shows further that students value the formative assessment elements to teaching and learning.

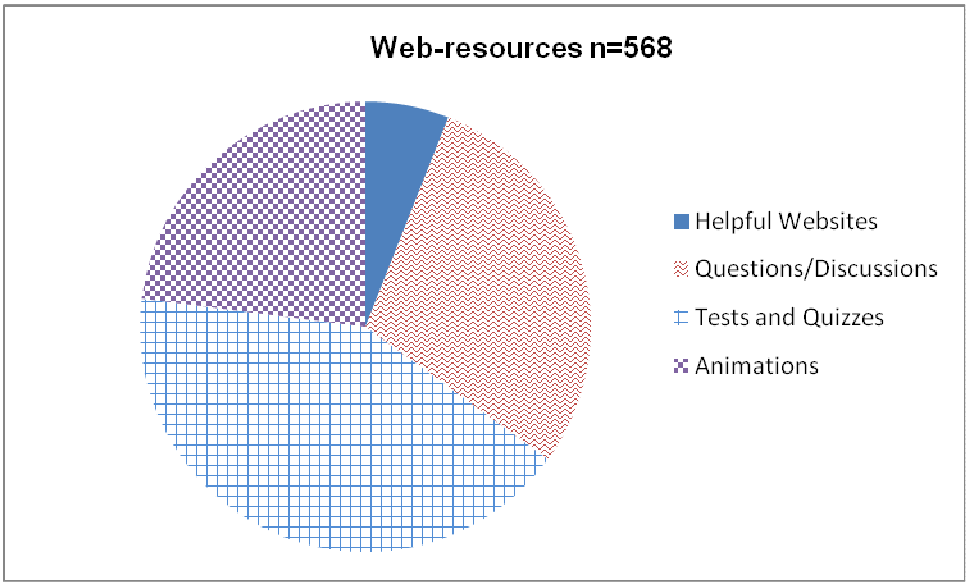


Figure 4.120 Usage of Web-Based Resources during Phase 3

4.7 Conclusion

This chapter has outlined the main findings of this study, including student performance in each diagnostic question pre- and post- intervention, student performance overall on the diagnostic tests, performance in students' concurrent Chemistry module at the time of the intervention Programme as well as students' attitudes and confidence levels towards Chemistry. The next chapter will now discuss these findings in more detail and the importance of these findings to the teaching and learning of Chemistry.

Chapter Five

Discussion

5.1 Introduction

This chapter will discuss the results of this study, which have been outlined in chapter 4, and the research questions that guided the study will be examined. The chapter is divided into various sections, each describing one theme and discussing the importance of the findings and results from the work.

5.2 Preparedness of Students

Despite the low numbers of students completing both a pre- and post-diagnostic test, a large number of students in each phase completed a pre-diagnostic test. Pre-diagnostic testing took place on the first tutorial session of each phase. In Phase 1, Phase 2, Part 1 and Phase 3 basic Chemistry concepts and ideas were focused on during the weekly tutorials. The same pre-diagnostic test was used to test these basic Chemistry areas in each phase. In total, 106 students completed pre-diagnostic tests for these phases. Although many of these students did not return to complete the post-diagnostic test, and some of these students chose not to participate fully in the Intervention Programme, the pre-tests they completed contained a lot of useful information. Of the 106 students that completed pre-tests, 37% had studied Chemistry for their Leaving Certificate Examination and 63% of the students had no experience of Chemistry beyond Junior Certificate Science. However, 100% of these students had completed a module in 'General Chemistry' in the previous academic semester. Despite this, the average mark students achieved in the pre-test was 38%. Correction of the pre-tests showed that most of the students were showing the same misconceptions and performed poorly in the same questions, see Figure 4. What is interesting is that whether students had studied Chemistry before University or not, the same areas were proving difficult for them. This was obvious in the results of certain questions on the pre-diagnostic test, so much so, that many students chose the same incorrect option for questions, illustrating further that they share similar misconceptions. This, in itself is useful information as it provides evidence that there is a general lack of preparedness of students who are entering Chemistry courses in third level, with or without a Chemistry background.

One possible explanation for this finding is that, even though the students have experience of studying Chemistry either for their Leaving Certificate Chemistry Examination or during their first year 'General Chemistry' module, they are building their new knowledge on a poor foundation and do not completely understand the underlying concepts that are necessary for meaningful learning to occur. Many students opt to rote learn in order to pass their examinations and are more concerned with mastering past examination questions and getting the correct answer rather than understanding how they are getting a particular answer and what steps they take to work out an answer. This appears to be the case with both the Leaving Certificate Examination and also University Examinations (Hyland, 2011; Flynn, 2011). In Phase 2, Part 2, the tutorials focused on chemical calculations and the mole concept and the pre- and post-diagnostic tests for this part were designed to test those particular areas. As only one group of students got the opportunity to participate in this part, it is impossible to say if students were having the same difficulties in certain areas and showing the same misconceptions in particular questions on the pre-test. 37 students completed pre-diagnostic tests in Phase 2, Part 2 and the average mark achieved by the students was 34%.

Another factor that may have played a part in students' low marks in the pre-diagnostic tests is the cognitive level of the students. Previous work on both undergraduate and school students show that the majority of these students are at the concrete level which is inadequate for the successful study of Chemistry (Sheehan, 2010). This suggests that these students are not prepared for the demands they meet at third level and will find the abstract concepts of Chemistry and Mathematics difficult to comprehend and this is a key factor in poor performance in Chemistry.

The level of preparedness of students for Chemistry is a factor that needs immediate attention as it is clear from the results of this study that the majority of students entering third level Chemistry courses do not have an adequate level of understanding of Chemistry, and this is not altered even after completing a 'General Chemistry' module. These students will then progress into their second year of study and throughout the rest of their course maintaining the same misconceptions and continue making the same mistakes and performing poorly in any areas where they need to apply their existing Chemistry knowledge. It is of vital importance that these students are given the help and support that they need to overcome their weaknesses and difficulties early in their academic careers, as misconceptions can become more 'rooted' and persistent as time goes by. Further study of Chemistry merely adds layers of knowledge on an inadequate foundation, much like painting over a rusted and pitted surface – the underlying problems remain Reid, 2008; Johnstone 1997; Childs, 2010).

5.3 The Value of Formative Assessment

The value of formative assessment has become apparent based on the findings of this study (Sadler, 1998). The use of formative assessment throughout the Intervention Programme has had a positive impact on students' progress through the programme. It was mentioned by all the interviewed students (n=6) as something that they would like to see more of in lecture situations. It allows students to gain instant feedback on their work or their understanding of a topic. As well as this, it allows the lecturer/teacher to ascertain where exactly the students are in terms of their learning and provides a valuable insight into whether students have mastered a particular area or not before moving onto the next topic (Boston, 2002). Formative assessment can be introduced into the lecture theatre in a number of ways ranging from the use of an interactive response system in the form of clickers to a more cost effective method of using coloured card to develop a traffic light system, green cards for full understanding of a topic, amber card for uncertainty of a topic and red card for no understanding of the topic. Simple techniques like these can have a major effect on the teaching and learning of weaker students.

5.4 The Effect of the Intervention Programme

The Intervention Programme has shown positive results in a number of areas, which will be divided into different sections and discussed below. More detailed information on the analysis of these results can be found in chapter 4.

5.4.1 Performance in Pre- and Post-Diagnostic Test

All students who participated in the Intervention Programme improved their mark in the post-diagnostic test and this was significant in some groups (see Figure 4.58). This was to be expected as the content of the weekly tutorials was based on the areas that students performed poorly in on the pre-diagnostic test, so that their specific problems were addressed. This was an attempt to teach '*smarter*' by identifying and targeting specific areas where students have misconceptions or difficulties (Perkins, 2007). However, despite this, it shows that even a nine or ten week programme of tutorials, providing targeted help and support to 'at-risk' students can really make an improvement in their understanding of basic chemical concepts and calculations. All students improved their score in the post-diagnostic test, however some students still got the same questions wrong in the post-test that they got incorrect in the pre-diagnostic test. This shows that despite focusing on specific problem areas, some students might need more time to fully comprehend particular concepts and this might take longer that a nine or ten week programme.

5.4.2 Concurrent Chemistry Module Performance

Students who participated in the Intervention Programme did so in parallel with a concurrent Chemistry module. All analysis showed that the average results were better but, in some cases the difference was significant and in others it wasn't. The marks of those who attended six or more tutorials were examined and they performed better in their concurrent Chemistry module than students who did not participate in the programme. The tutorial material taught during the Intervention Programme were not linked in any way to the modules students were studying at the time and did not cover material directly related to their examinations in the modules. Instead, they focused on basic chemical concepts, which students had difficulty in. This shows that if students can fully understand the underlying concepts in Chemistry, it is easier for them to construct new Chemistry knowledge (Gabel, 1999). Conversely a lack of basic conceptual understanding in Chemistry hinders performance in more advanced modules (Perkins, 1993).

5.4.3 Attitude and Confidence levels in Chemistry

All students who participated in the Intervention Programme showed an improvement in their attitude and confidence levels in Chemistry in the post-attitude/confidence test. This could be due to a number of reasons, such as the smaller group numbers in each tutorial session. Some students prefer to learn in a smaller class setting rather than a large lecture style setting, and the intervention tutorials suited these students much more, as the average attendance was around 20 students. This created a friendly learning atmosphere for the students, where they felt they could ask any questions they wanted. Students mentioned the small class setting as an advantage and something they liked about the Intervention Programme. As well as this, there was a lot of opportunity during the tutorials for the students to work in groups or in pairs and this peer-teaching and learning strategy worked well for the students, as they got to know each other and also were more comfortable discussing their difficulties with each other. Online resources were made available to participating students, which included tests and quizzes each week on the topic that had been covered in the tutorial session. Students regularly completed these exercises and received instant feedback on their performance. If they received high marks from the quiz, it meant that they had mastered that particular topic and this gave them more confidence in that particular area. Student attitudes towards Chemistry were generally positive at the beginning of the tutorials and remained positive throughout the Intervention Programme. This will be discussed in more detail in Section 5.5.

5.5 Student Interviews

The interviews that were carried out with the students provided a valuable insight into a variety of things, including the areas they found particularly difficult in Chemistry, their attitude and feelings towards Chemistry, their thoughts on the Intervention Programme and improvements they would make, the way Chemistry is taught in their lectures and what their ideal learning environment would be. Findings from the Interviews can be found in Section 4.4.2.7.

5.5.1 Difficulties Encountered when Learning Chemistry

a) One area in Chemistry that students mentioned as difficult during the course of the interviews was the language of Chemistry. They spoke about finding the vocabulary used in Chemistry very confusing and they did not understand it. If they do not understand one word in the sentence then they cannot understand any of it, as that particular word acts as a barrier to comprehending the remaining information. As well as this, they mentioned that frequently they do not understand the vocabulary used in examination questions and this can hinder their chances of successfully completing the question, they may know the material needed to answer the question, but cannot understand what the question is asking them to do, and so fail to answer it. The language of Chemistry needs to be addressed when teaching students new to the subject (Wellington and Osborne, 2001; Snow, 2010).

b) Chemical calculations posed another difficult area for students and they spoke about using learned-off formulae to solve problems. They admitted to not understanding what the formula meant or how it was derived, but once they could plug in the numbers and get the right answers that was all they cared about. This reliance on algorithms shows that the students are more concerned with getting the right answers to do well in their examinations than fully understanding the underpinning concept. Often this is the approach they are taught to use 'using the formula', rather than one starting from first principles and seeking to develop understanding. As a result meaningful learning outcomes are not met (Cartrette and Bodner, 2010). It is of vital importance to link learning outcomes with the assessment methods employed (Biggs, 1996).

c) Students spoke about having difficulty linking what they do in lectures with the practical activities that they carry out in the laboratory. For the most part, they follow carefully the steps outlined in their laboratory manuals but cannot see the relevance of purpose of what they are doing. They also mentioned major difficulty during the write-up of the practical activities, as they do not know what they were looking for or supposed to be calculating (Meester and Maskil, 1995; Reid and Shah, 2007). Domin (2007) investigated two approaches to laboratory teaching, the traditional method of following ‘cookbook’ recipe style procedures to achieve a pre-determined result, the other being a non-traditional student-centered approach. Results showed that students were more cognitively engaged in learning during the non-traditional approach.

5.5.2 Attitudes to Chemistry and to the Intervention Programme

All students that were interviewed said they had a positive attitude towards Chemistry and liked the subject but they didn’t enjoy studying it. They felt it was too difficult and they had to spend double the time studying Chemistry, than they had to do with the other subjects they were taking at the same time.
Students were very positive about the Intervention Programme and felt it was a worthwhile programme to participate in. They felt they had improved their Chemistry knowledge by attending the weekly tutorials and found it easier to follow their concurrent Chemistry modules as a result. 100% (n=6) of the interviewed students mentioned the use of formative assessment as something that worked well for them during the Intervention Programme. Students liked the idea of studying what was covered the previous week and then being tested on it and knowing instantly if they had mastered it or needed to spend more time on it (Boston, 2002). More information on formative assessment is given in Section 2.5.5. Small class sizes were mentioned as something the students liked about the programme as they felt much more comfortable in this type of setting. They got the opportunity to ask questions and share opinions when they needed to. Students felt that the online resources were beneficial and provided flexibility as they explained how convenient it was to log into the online site at home, outside of college hours, to complete work or do a test or quiz. The suggestions that students made about the Intervention Programme will be discussed in the recommendations Section 6.3.

5.5.3 Learning Environment (Lectures)

The students find the pace of their ‘General Chemistry’ lectures very fast and often find it hard to keep up. They mentioned moving on to new topics during each lecture that can only be understood if the previous topic has been fully comprehended. Despite spending time researching the chemical topics and attempting to understand them, again, the language used in many of the textbooks hinders their success. They often opt instead to study the past examination questions, learn off by rote how to complete the questions and re-write the answers for the examinations. When they then move on to another Chemistry module, the cycle is repeated; failure to understand leads to rote learning of past examination questions in order to pass the end of term examinations (Boujaoude, 2007).

5.6 Student Motivation and Attendance

As stated throughout this study, poor and inconsistent attendance affected the validity of the results. This is a major factor in student achievement and is closely linked to student motivation. Many students entering third level do not have the required skills and are less prepared (O'Connor, 2006). They often struggle with things such as study skills, lack of prior academic success and also poor mathematical backgrounds Due to the voluntary nature of the Intervention Programme, it was difficult to encourage students to attend the weekly tutorial sessions. It is not only voluntary tutorials that have a problem with low student attendance, lectures and laboratory practical sessions, which are a compulsory component to students' courses of study, are also often poorly attended. If students' motivation can be improved towards Chemistry, this will have a direct effect on student attendance. Allowing extra course credits for attending support tutorials may act as an incentive to some students. However, inevitably it is students' intrinsic motivation that needs to be improved. Research has shown that technology tools such as multimedia, simulations and problem-solving programmes have been shown to have a beneficial effect on students' motivation to learn because they make learning interesting and meaningful (Marr, 2000). As well as this, Snowman and Biehler (2006) suggest the following points for improving student motivation to learn:

- Use of behavioural techniques to help students exert themselves and work towards goals
- Making sure that students know what they are to do, how to proceed and how to determine when they have achieved their goals

- Encouraging low- achieving students to attribute success to a combination of ability and effort and failure to insufficient effort
- Maximising factors that appeal to both personal and situational interests
- Trying to make learning interesting by emphasizing activity, investigation, adventure, social interaction and usefulness.

By incorporating these suggestions into the teaching and learning of Chemistry, it is hoped they will play a role in increasing student confidence towards the subject and in turn improve student motivation.

5.7. Metacognition

Metacognition is thinking about thinking. Taylor (1999) defines metacognition as “an appreciation of what one already knows, together with a correct apprehension of the learning task and what knowledge and skills it requires.” The more students are aware of their thinking processes as they learn, the more self aware they become. It is important to develop metacognition skills in students as it helps them become more efficient in their learning by helping them to evaluate their own learning. Metacognition skills can be developed through use of self-testing for example the online quizzes used in the Intervention Programme. These allowed the students the opportunity to assess their own learning and allows them to further direct their learning leading to more meaningful understanding (Darling-Hammond *et al,*. 2003).

5.8 Limitations

The main limitation of this Intervention Programme was the voluntary nature of participation. Only a proportion of the students ‘at risk’ participated and even for those who did attend, their attendance was inconsistent, particularly in Phase 2. Results from Phase 2 were affected by the low attendance rates; however, the small sample size was adequate to show significant results. It seems likely that the better and more motivated students took up this opportunity of extra tutorials to improve their understanding of Chemistry, and this may be reflected in the performance in the concurrent and subsequent examinations. Thus the improvements noticed may also be due to the self-selected nature of the sample.

Another limitation was that Phase 1 was started during the students' second year, which may be too late to intervene; this was rectified in Phase 2, when tutorials began in students' first year of study. Also Phase 1 was run for one semester, whereas in Phase 2 this was extended to two semesters, to allow for greater coverage of basic Chemistry topics. Greater participation by students and more consistency in attendance would have improved the validity of these results.

Chapter Six

Conclusion

6.1 Introduction

In this chapter, the main findings from the study will be summarised in answering the research questions posed in Chapter One. Recommendations will be given based on the findings and planned future work will be given.

6.2 Research Questions

The research questions posed at the beginning of this study were outlined in Chapter One. Here, these questions will now be answered according to the research findings.

1. **How well prepared are students to study Chemistry at third level and do they share common misconceptions?**

Results from the pre-diagnsotic tests show that the majority of students perform poorly in the pre-test whether they have studied Leaving Certificate Chemistry or not. They also show that many of the students share common misconceptions. In the option questions, many students chose the same incorrect answers. These results suggest that many students are not prepared for the demands of third level study.

2. **Can diagnostic tests, that identify students' prior chemical knowledge and misconceptions, be used to design an effective Intervention Programme?**

Diagnostic testing has proved to be a very valuable tool in teaching and learning environments. This study has demonstrated the value of using diagnostic testing to assess weakenesses in the students' background knowledge and understanding that prevents them from succeeding in further study of Chemistry. By pinpointing their misconceptions, it is possible to design and develop targeted help and support for those who need it.

3. What effect does prior Mathematics background have on student performance on pre- and post-diagnostic tests?

Students who had studied Mathematics for their Leaving Certificate examination performed better in both the pre- and post-diagnostic tests than students who had no experience of Mathematics at Leaving Certificate level.This further establishes the fact that Chemistry and Mathematics are very closely linked and a good understanding of both is imperative to succeed in either subject.

4. Can a targeted Intervention Programme improve students' performance in the post-disgnostic test compared to their performance in the pre-diagnostic test?

A targeted Intervention Programme can have a very positive impact on student performance in the pre- and post-diagnostic tests. Tailoring tutorials to the students' actual needs, that is teaching 'smarter' gives the opportunity to deal with fundamental problems, for example, persistent chemical miscoceptions and lack of prior knowledge, that undermine their attempts to study Chemistry further. All students improved their score in the post-diagnostic test compared to their score in the pre-test.

5. How does attendance at the Intervention Programme make a difference in the students' overall performance in their concurrent Chemistry modules?

Attendance at the Intervention Programme does make a difference on students' performance in their concurrent Chemistry module. Students who participated in the Intervention Programme by attending 6 or more tutorials obtained a better average mark in the written part of their Chemistry module examination than students who chose not to participate in the programme. In some cases, the difference in marks was significant and in others it wasn't.

6. **Can students' attitude and confidence towards Chemistry be improved by taking part in a targeted Intervention Programme?**

From analysis of the pre- and post-attitude and confidence tests, it is clear that participation in the Intervention Programme has impacted positively on students' attitudes and confidence levels towards Chemistry. Student confidence levels improved in a number of areas including 'Understanding key concepts of Chemistry and explain topics in your own words' and 'Tutoring another student in a first year Chemistry module'.

6.3 Recommendations

Based on the findings of this study, the following are suggested recommendations:

<u>Intervention Programme and Diagnostic Testing</u>

- The Intervention Programme should be started earlier in the students' academic careers, ideally in their first year of study, when they are first faced with Chemistry modules and need extra support and help in that area. They should start in semester 1, particularly for students without Leaving Certificate Chemistry, and continue for at least 2 semesters, or until they reach a specified level of performance.
- The use of diagnostic testing is a valuable tool in identifying students' particular difficulties and misconceptions. It provides an opportunity to address these areas of difficulty and pinpoint exactly where students are struggling. Diagnostic testing is something that could be incorporated into any subject. We need to know where students are 'at' and teach accordingly, and we need to teach smarter, not harder (Perkins, 2007).
- Low–achieving students or under-prepared students should be identified and provided with targeted support for their individual needs, through focused tutorials, at the start of their course.

- Students should be followed-up at the end their course of study to investigate if their performance and drop-out rates have been affected by the Intervention Programme.

Learning Environment

- Lecturers of first year Chemistry modules should be aware of common areas of student difficulties and misconceptions held by students especially those with weak backgrounds in Chemistry and make sure they are deliberately addressed in the teaching of introductory Chemistry. For example the use of a diagnostic question at various places through the course can help show what misconceptions students may or may not hold before moving on to the next section of the course.
- Formative assessment should be incorporated into a lecture setting to address the wide range of abilities and diversities in the lecture theatre. This can be done effectively in many ways, especially by using 'clickers' response systems (Flynn, 2011; Wagner, 2009).
- Academic credit should be awarded for students who attend extra tutorials and this might hopefully improve attendance at these types of tutorials and also encourage those students who are in need of extra support to attend.
- A range of teaching methodologies such as pair work, peer teaching and assessment and problem solving should be used to accommodate the variety of abilities and learning styles found among students.
- Thinking skills should be developed and integrated into the content of Chemistry courses. This infusion model would allow students to develop their understanding and competence in the subject while also improving their thinking skills (Sheehan, 2010; Spencer, 1999).

Interview Recommendations

- Special attention should be given to the importance of understanding the language of Chemistry in order to understand and progress in Chemistry (Seery, 2011).

- Students should be discouraged from using rote formulae to answer problems; they should be taught to solve problems and derive solutions from first principles, and given credit for using this approach in examinations.
- Lecturers need to take account of the diversities in chemical background of their students and should deliberately pace the introduction and development of new material to the students' abilities (Reid 2008; Johnstone, 2006).
- More efforts should be made to help students make connections between the theory and practical aspects of their Chemistry courses. If these two parts of Chemistry are made more explicit to students, it will help them to inter-relate the two aspects of the course, and provide a relevant contrast from the theory.

6.4 Dissemination of the Findings and Future Work

Throughout the last two years, the researcher has presented this work at numerous Irish and International conferences, and has also published a peer-reviewed paper which can be seen at the Appendices Section. This work is being continued in the University of Limerick, in the form of support tutorials. Weaker students without a Chemistry background are identified and grouped together so that they can be provided with extra support in Chemistry. These students are in their first year of study and are concurrently studying a 'General Chemistry' Module. Initial results are positive. An alternative approach used in some institutions would be to run two different streams in first year for those with or without Chemistry.

6.5 Conclusion

This chapter has outlined the main conclusions of this study as well as giving recommendations based on the findings. The problem of student Chemistry misconceptions in students needs to be addressed in the mainstream Chemistry programme for them to be dealt with successfully. 'Early and Often', might be a useful slogan for Intervention Programmes designed to improve student retention in Science degrees.

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Appendix A

Pre- and Post-Diagnostic Tests

(Phase 1, Phase 2 - Part 1 and Phase 3)

Pre- Diagnostic Test

1. How many atoms are in the formula $Al_2(SO_4)_3$?

3 __

5 __

17 __

2. The radioactive isotope ^{14}C has how many neutrons? (z = 6)

6 ___

8 ___

Other ___

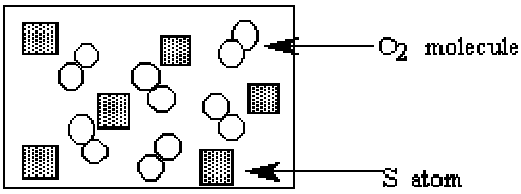
3. The identity of an element is determined by the number of which particle?

Protons ___

Neutrons ___

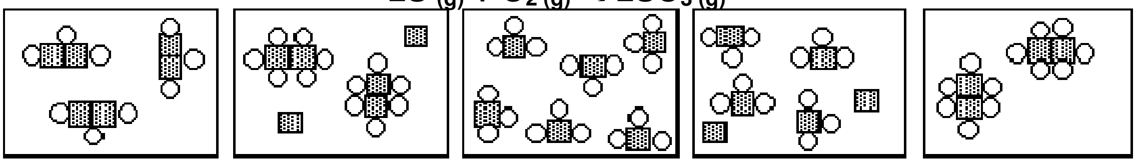
Electrons ___

4. The diagram represents a mixture of S atoms and O_2 molecules in a closed container.



Which diagram shows the results after the mixture reacts as completely as possible according to the equation?

$$2S_{(g)} + O_{2\,(g)} \rightarrow 2SO_{3\,(g)}$$



(a) (b) (c) (d) (e)

5. How many moles of ions are there per 1 mole of $Al_2(SO_4)_3$?

2 ___

3 ___

5 ___

6. Write the electronic configuration (s,p) of Chlorine. (z = 17)

7. How many moles of Aluminium atoms are there in 9 x 10^{22} atoms of aluminium? (Relative Molecular mass Al = 13)

8. Write the formula for Sodium Sulfide

9. What is the oxidation number of the N atom in the NO_3^- ion?

10. Use the VSEPR theory to deduce the shape of the ammonia molecule, NH_3

11. Write the formula of Sodium Sulphate

12. Balance the following equation

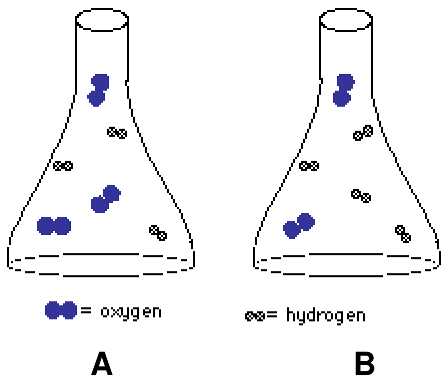
$K_{(s)} + H_2O \rightarrow KOH_{(aq)} + H_{2\,(g)}$

13. Magnesium reacts with oxygen to produce Magnesium oxide according to the equation:

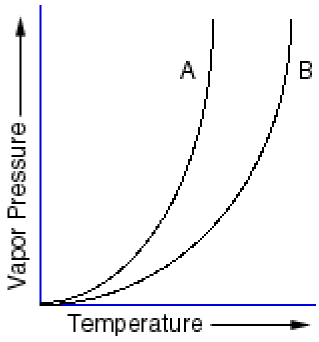
$2Mg_{(g)} + O_{2\,(g)} \rightarrow 2MgO_{(g)}$

If a student burns 9g of magnesium in excess oxygen (i.e. there is plenty of oxygen present to ensure that all of the magnesium reacts), what mass of Magnesium Oxide will be formed?

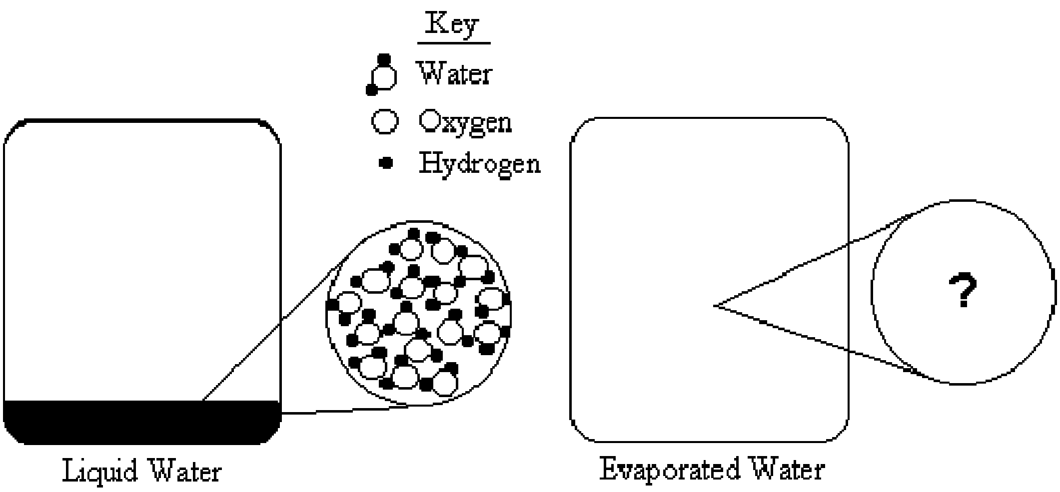
14. Which of the flasks below will contain a mixture when all the hydrogen reacts with oxygen to give water? (H_2O)



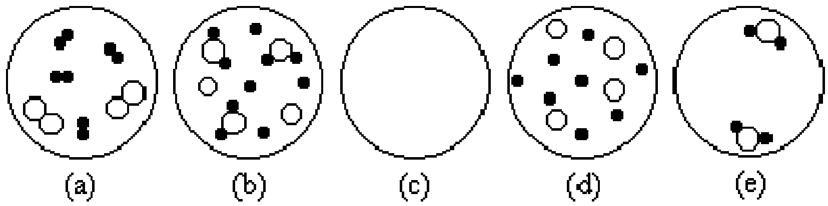
15. Drops of water and ethanol are placed on an overhead projector and the ethanol drop is seen to evaporate more rapidly. The graph below compares the vapour pressures of ethanol and water. Which curve corresponds to ethanol?



16. The circle on the left shows a magnified view of a very small portion of liquid water in a closed container.



What would the magnified view show after the water evaporates?



Post-Diagnostic Test

1. How many atoms are in the formula $Na_2Cr_2O_7$?

4 __

11 __

15 __

2. The radioactive isotope ^{22}Ne has how many neutrons? (z = 10)

12___

10___

Other ___

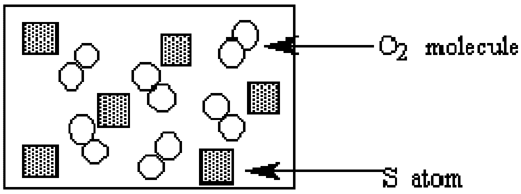
3. The identity of an element is determined by the number of which particle?

Protons ___

Neutrons ___

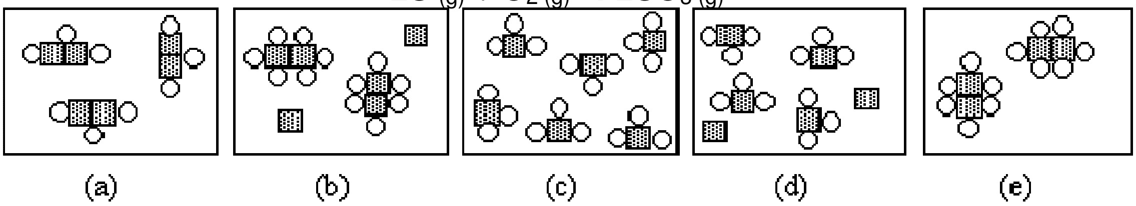
Electrons ___

4. The diagram represents a mixture of S atoms and O_2 molecules in a closed container.



Which diagram shows the results after the mixture reacts as completely as possible according to the equation?

$$2S_{(g)} + O_{2\,(g)} \rightarrow 2SO_{3\,(g)}$$



5. How many moles of ions are there per 1 mole of $NaHCO_3$?

2 ___

3 ___

5 ___

6. Write the electronic configuration (s,p) of S. (z = 16)

7. How many moles of Carbon atoms are there in 9 x 10^{22} atoms of carbon?

8. Write the formula for Sodium Carbonate

9. What is the oxidation number of Sulfur in $Na_2S_2O_3$?

10. Use the VSEPR theory to deduce the shape of the methane molecule, CH_4

11. Write the formula of Calcium Carbide?

12. Balance the following equation

$HNO_{3\,(aq)}$ + $Ca(OH)_{2\,(s)}$ → $Ca(NO_3)_{2\,(aq)}$ + $H_2O_{(g)}$

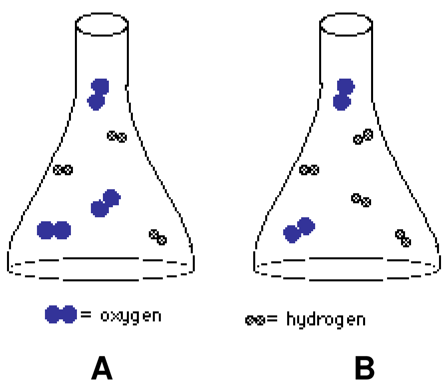
13. **A piece of Calcium weighing 0.500g was added to water and the gas evolved was collected and it's volume converted to S.T.P. The resulting solution was alkaline due to the formation of Calcium Hydroxide.**

(a)What gas is evolved?

____

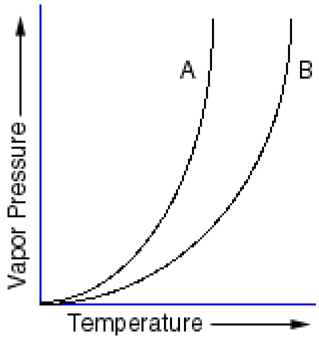
(b) How many moles of Hydrochloric acid would be needed to neutralise the calcium hydroxide?

14. **Which of the flasks below will contain a mixture when all the hydrogen reacts with oxygen to give water? (H_2O)**

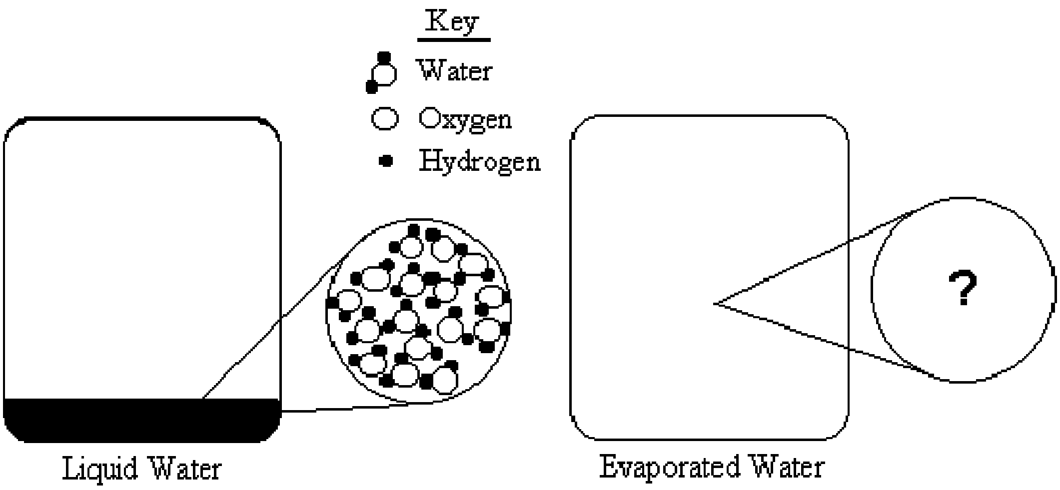


15. **Drops of water and ethanol are placed on an overhead projector and the ethanol drop is seen to evaporate more rapidly. The graph below**

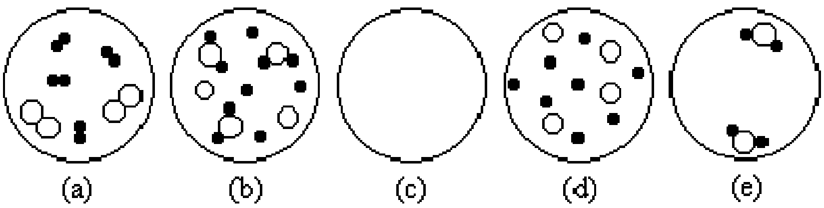
compares the vapour pressures of ethanol and water. Which curve corresponds to ethanol?



16. The circle on the left shows a magnified view of a very small portion of liquid water in a closed container.



What would the magnified view show after the water evaporates?



Appendix B

Pre- and Post-Diagnostic Tests

(Phase 2 - Part 2)

Pre-Diagnostic Test

1) What is the molar mass of oxalic acid $(COOH)_2$?

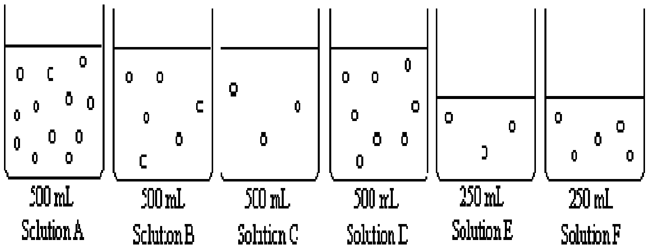
2) What is the molar mass of acetic acid (CH_3CO_2H)?

3) How many moles of acetic acid are there in a 10.0g sample?

4) To produce 1 litre of a 0.15M solution of oxalic acid, what mass of acid do we need?

5) How many atoms are there in 34.0g of Carbon?

6) **The drawings below represent beakers of aqueous solutions.**



Answer the following questions.

Put A, B, C, D, E or F in the spaces provided:

a) Which solution is most concentrated? Solution ____

b) Which solution is least concentrated? Solution ____

c) Which two solutions have the same concentration? Solution ____ and _____

d) When Solutions E and F are combined, the resulting solution has the same concentration as Solution ___

e) If you evaporate off half of the water in Solution B, the resulting solution has the same concentration as Solution _____.

7) A compound containing only nitrogen and oxygen was found to contain 2.1g of nitrogen and 1.2g of oxygen. What is the mass percent composition of oxygen and nitrogen in this compound?

8) Which is the correct mass percent composition of sodium nitrate, $NaNO_3$?

9) 5.00g of calcium carbonate was dissolved in excess 0.150 M hydrochloric acid and dissolved according to the equation:

$$CaCO_{3(s)} + 2HCL_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O$$

Answer the following questions:

a) How many moles of calcium carbonate were present in 5.00g $CaCO_{3(s)}$?

b) What volume of 0.150 M HCL $_{(aq)}$ would be used up reacting with this mass of $CaCO_{3(s)}$?

c) How many moles and what mass of $CaCl_2$ would be produced?

d) What volume of $CO_{2(g)}$ would be produced at STP from the reaction of 5.00g of $CaCO_3$?

10) Ethene, C_2H_4 can be made from ethanol C_2H_5OH according to the following equation:

$$C_2H_5OH \rightarrow C_2H_4 + H_2O$$

Starting with 20g of ethanol, 8g of ethene was obtained. Calculate the percentage yield of ethene.

11) 2.50g of iron (II) sulphate-7-water, $FeSO_4.7H_2O$, was dissolved in water and made up to 250 cm^3. Iron (II) sulphate reacts with sodium phosphate according to the equation:

$$3Fe(II)SO_{4(aq)} + 2Na_3PO_{4(aq)} \rightarrow Fe_3^{(II)}(PO_4)_{2(s)} + 3Na_2SO_{4(aq)}$$

a) Calculate the number of moles of iron (II) ions in the solution and hence the molarity of the solution.

b) How many moles of sodium phosphate would be needed to react completely with all the iron$^{(II)}$ sulphate in the solution made above?

c) What volume of 0.100M sodium phosphate would be needed to react completely with all the iron$^{(II)}$ sulphate in the solution made above?

d) What mass of $Fe_3^{(II)}(PO_4)_{2\,(s)}$ would be produced in the reaction above if all the iron$^{(II)}$ sulphate solution was reacted with excess sodium phosphate?

Post-Diagnostic Test

1) What is the molar mass of oxalic acid $(COOH)_2$?

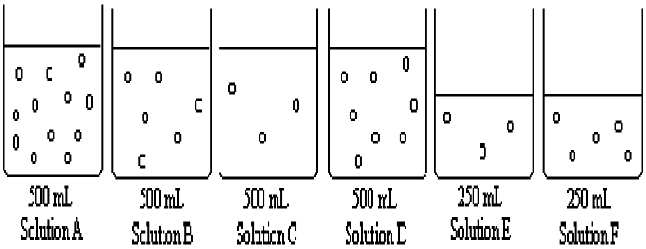
2) What is the molar mass of acetic acid $Ca_3(PO_4)_2$?

3) How many moles of sulfuric acid, H_2SO_4 are there in a 10.0g sample?

4) To produce 1 litre of a 0.15M solution of oxalic acid, what mass of acid do we need?

5) How many atoms are there in 117g of water?

6) The drawings below represent beakers of aqueous solutions.



Answer the following questions.

Put A, B, C, D, E or F in the spaces provided:

a) Which solution is most concentrated? Solution ____

b) Which solution is least concentrated? Solution ____

c) Which two solutions have the same concentration? Solution ____ and _____

d) When Solutions E and F are combined, the resulting solution has the same concentration as Solution ___

e) If you evaporate off half of the water in Solution B, the resulting solution has the same concentration as Solution _____.

7) A compound containing only nitrogen and oxygen was found to contain 2.1g of nitrogen and 1.2g of oxygen. What is the mass percent composition of oxygen and nitrogen in this compound?

8) Which is the correct mass percent composition of sodium nitrate, $NaNO_3$?

9) 5.00g of calcium carbonate was dissolved in excess 0.150 M hydrochloric acid and dissolved according to the equation:

$$CaCO_{3(s)} + 2HCL_{(aq)} \rightarrow CaCl_{2(aq)} + CO_{2(g)} + H_2O$$

Answer the following questions:

a) How many moles of calcium carbonate were present in 5.00g $CaCO_{3(s)}$?

b) What volume of 0.150 M HCL $_{(aq)}$ would be used up reacting with this mass of $CaCO_{3(s)}$?

c) How many moles and what mass of $CaCl_2$ would be produced?

d) What volume of $CO_{2(g)}$ would be produced at STP from the reaction of 5.00g of $CaCO_3$?

10) Ethene, C_2H_4 can be made from ethanol C_2H_5OH according to the following equation:

$$C_2H_5OH \rightarrow C_2H_4 + H_2O$$

Starting with 20g of ethanol, 8g of ethene was obtained. Calculate the percentage yield of ethene.

11) 2.50g of iron (II) sulphate-7-water, $FeSO_4.7H_2O$, was dissolved in water and made up to 250 cm^3. Iron (II) sulphate reacts with sodium phosphate according to the equation:

$$3Fe(II)SO_{4(aq)} + 2Na_3PO_{4(aq)} \rightarrow Fe_3^{(II)}(PO_4)_{2(s)} + 3Na_2SO_{4(aq)}$$

a) Calculate the number of moles of iron (II) ions in the solution and hence the molarity of the solution.

b) How many moles of sodium phosphate would be needed to react completely with all the iron$^{(II)}$ sulphate in the solution made above?

c) What volume of 0.100M sodium phosphate would be needed to react completely with all the iron$^{(II)}$ sulphate in the solution made above?

d) What mass of $Fe_3^{(II)}(PO_4)_{2\,(s)}$ would be produced in the reaction above if all the iron$^{(II)}$ sulphate solution was reacted with excess sodium phosphate?

Appendix C

Subject Information Sheet

Subject Consent Form

Subject Information Sheet

Retaining Weaker Students in Science Undergraduate Programmes

The Study:

This project aims to review literature on retention in student science programmes and to design, develop and evaluate an intervention programme which will in turn reduce drop out rates.

In particular the project wants to identify:

- The particular problems students have in science
- Student's misconceptions, cognitive level, ability to deal with abstract ideas and their background math level
- The measure of the students confidence and attitudes in relation to studying chemistry at third level and investigate how important this factor is

Participant Information:

You will be required to attend one hour weekly tutorials which cover Basic Chemistry topics. You will also be required to complete a pre and post concept test. Feedback on you progress after the tutorials will be available if requested via email.

This study is an expanded version of a pilot project that was run in UL in 2008. Results of this project show that students who attended the tutorials did significantly better not only the chemistry module that they were studying at the time but also in future chemistry modules that they undertook.

There are no risks involved in this study. All information gathered will remain confidential and used only for the purpose of this study. Academic records will be used. The information gathered will be stored safely with access only available to the investigator.

Contact Details:

Aine Regan
CES Dept.,
University of Limerick,
Limerick.
061-202486 or aine.regan@ul.ie

If you have concerns about this study and wish to contact someone independent, you may contact:

The Chairman of the University of Limerick Reseach Ethics Committee,
c/o Vice President and Academic and Registrar's Office, University of Limerick.

UNIVERSITY of LIMERICK
OLLSCOIL LUIMNIGH

Subject Consent Form

Retaining Weaker Students in Science Undergraduate Programmes

	Yes	No
• I have read and understood the subject information sheet	□	□
• I understand what the project is about, and what the results will be used for.	□	□
• I am fully aware of all of the procedures involving me and of any risks and benefits associated with the study.	□	□
• I know that my participation is voluntary and that I can withdraw from the project at any stage without giving any reason.	□	□
• I am aware that my results will be kept confidential	□	□

There are no risks involved in this study. All information gathered will remain confidential and used only for the purpose of this study. The information gathered will be stored safely with access only available to the investigator.
You are under no obligation to participate in this study. Should you have any questions or do not understand something, please contact me at aine.regan@ul.ie and I will clarify any issues that you are concerned about.
I agree to participate in the above study

______________________ ________________
Date *Signature of Participant*

______________________ ________________
Date *Signature of Investigator*

Appendix D

Background Information Sheet

UNIVERSITY of LIMERICK
OLLSCOIL LUIMNIGH

Background Information

Name ____

I.D. Number __________________________________

Class ____

Year ____

Please answer the following questions:

Did you study Chemistry at Leaving Certificate Level?

____

If so, what level Chemistry paper did you take?

____

What grade did you receive on your Chemistry paper?

____

Did you study Mathematics at Leaving Certificate Level?

____

If so, what level Mathematics paper did you take?

____

What grade did you receive on your Mathematics paper?

____

Appendix E

Attitude and Confidence Test

Chemistry Attitude/Confidence Test

Please circle the number corresponding to each question which best suits your response.

		confidence level					
	CONFIDENCE IN YOUR ABILITY TO…	**n/a**	**Very low**	**Low**	**Average**	**High**	**Very high**
1)	Understand key concepts of chemistry and explain topics in own words	0	1	2	3	4	5
2)	Choosing an appropriate formula to solve a chemistry problem	0	1	2	3	4	5
3)	Approach a chemistry problem in a systematic manner, working step by step	0	1	3	3	4	5
4)	Determine the appropriate units for a result determined using a formula	0	1	2	3	4	5
5)	Read the procedures for an experiment and conduct the experiment without supervision	0	1	2	3	4	5
6)	Tutor another student in a first year chemistry course	0	1	2	3	4	5
7)	Apply your knowledge of chemistry to the real world	0	1	2	3	4	5
8)	Understand other areas of science	0	1	2	3	4	5
9)	Succeed in this chemistry course	0	1	2	3	4	5
10)	Succeed in a chemistry-related discipline	0	1	2	3	4	5

Appendix F

Interview Questions

Interview Transcripts

Interview Questions

1. Which questions on the diagnostic tests did you most difficult?
2. What prior knowledge of Chemistry, if any, had you when you entered this course?
3. Why did you choose to do your course?
4. What area do you find most difficult in Chemistry and why?
5. How would you describe your attitude to Chemistry?
6. Has your attitude towards Chemistry influenced your motivation to study Chemistry/dedication to the subject?
7. How important do you think attendance is at your lectures, laboratory sessions and tutorials?
8. What resources do you use to help your understanding of Chemistry? What are the most effective study aids?
9. Do you work co-operatively with people in your class on Chemistry?
10. Describe your ideal learning environment.
11. How effective were the two parts of Phase 2 of the Intervention Programme?
12. Any recommendations/suggestions for future Intervention Programmes?

Student A

1. What questions from the post-diagnostic test did you find most difficult?
Am…well compared to the first one I did, it literally, and it was my own fault it just went out of my head. I lost concentration or whatever and I found it actually very frustrating whereas the first time I did it I was happier with it and had no problems but there was something where it was talking about a solution, a solution on the left and a solution on the right and I couldn't figure out which they were talking about. I had to leave it and come back to it afterwards, I can't find which one it is there now. I had no problem with the last one because the first time around once I remembered, I had an idea that you add in the $7H_2O$ it was part of that. I had no problem with 6, the diagram question. I couldn't remember, you know my little one line formula, vdm or whatever. Now I got away without it but that annoyed me because I had my 3 other little formulas about the number of moles and if I had the triangle I would have been a lot more relaxed.

2. What prior knowledge, if any did you have coming into your course?
I had chemistry for the leaving certificate and I loved it but I was absolutely useless at it and I decided to drop it for the exam because when I was doing chemistry for the leaving cert, on my Christmas test I got 36%. My parents got me grinds, your man was very good, I went into the pre I got 19% after getting grinds. I loved the subject but I dropped it altogether and I said that's it and I concentrated on all the others, I could get the points I needed with the others. The morning of the chemistry exam I decided ill go in. If you have a fail you don't have to tell anyone but if you get a pass so what and I got a B. it just fell into place in the morning. I loved it you see but useless at it and it just fell into place I don't know how or why.Exams never bothered me I failed them all my life through primary school and secondary school, the only thing I was ever good at was maths and maths came naturally to me, nothing else I was just lazy. That was the only chemistry experience I had. I came into this course because I do chemical training so I wanted to get a better background of chemistry and biology, just purely if someone ask me a question I have a bit more background knowledge that I can answer. This course was brilliant, the level of chemistry in it is ideal for me.
As you see the stuff you remember it, atoms and molecules it jogs your memory you still have to learn it, you are still learning it from scratch but you recognise terms and all of that and the number of moles.
I don't think it would have made any difference at [studying Chem @ LC] all because that was 20 years ago so it's not like I remembered enough chemistry that would benefit. Although I did a tiny bit in the diploma in health and safety in '05-'06. We did very basic theory on what atoms are and what an acid is, that sort of stuff, very, very basic. That might have helped as well.

3. What area in chemistry is most difficult for you?
What reacts with what? There's an overall link and it's still missing for me I want to be able to look at a msds sheet and see what type of chemical that is and if it reacts with something what will happen. You know like an acid and a base will give you a salt and water I can remember that one but some of the others I cant remember. If someone says

to me react this chemical with that chemical what will you get, I struggle big time on that and I actually need to get that for the inorganic exam we have in a few weeks time, that's my biggest weakness. The mole is fine. I did an hour or 2 over the summer I was trying not to lose what I had learned the previous semester so I had a bit of spare time but of course you do an hour or 2 and you say you don't need to any more of this, you know what I mean. When I actually did the pre-test, because it was all moles I flew through it.

4. What kind of an attitude do you have towards chemistry?

I love it, I love it but I do find in the practical side, half the labs are rubbish. The theory is very good, the material is very good. I wouldn't hand up those procedures in an industrial environment. They are terribly written they are very hard to follow but even when they don't work out the lab technicians will tell you the chemicals are probably not pure, it could be the wrong solution and all the rest of it. Why bother? What's the point? There's only one maybe 2 labs this time around that I think, the aluminium one was very good actually and was very good when you were writing it up for learning stuff and none of the rest. I don't think there's a mismatch between the theory covered in lectures and the labs but at the same time literally when you go in there, into the lab I haven't a god damn clue what that lab is going to be about, I haven't a notion. Now that's our own fault for not looking at it beforehand but once or twice I sat down to look at a lab beforehand, you go for the one that's next in the book and then we went into the lab and you either weren't doing that lab or we were skipping on and doing another one first. Tell us the week before this is the actual lab you are doing and then we will put the time in beforehand but in fairness trying to find the time to put in, working as well as going to college is...is a bit hard you know, but more preparation before the lab would probably make more sense.

7oclock on a Saturday morning, 7oclock on a Sunday morning, I'm studying. I have to because I have to work whatever I get during the week and I finish 9 or 10 at night. I'm not a fast learner, I don't just read something and pick it up I have to read it and read it and write it and write it and it will eventually filter through. Some people have a photographic memory, they read it and they know it and can remember it I can't, I could read an article and I could just look down and wouldn't have a clue what I just read. It's purely down to concentration

5. How important is attendance at lectures, labs and tutorials?

You couldn't get by there's stuff given out in the lectures, you know the notes are there but some of the notes weren't given out. It's hard to scribble down the notes and listen at the same time. If you have notes with pointers written in and if you miss what was said at least you know what was being talked about and you can go away and look it up at home. There's nothing worse than either having a full list of notes which they read word for word which just bores you so you won't go or having none, one is as bad as the other. In terms of attending the labs I get nothing out of them, I attend and go through the motions but the way I look at it its 2 hours out of my life I could spend studying instead of doing labs.

Your tutorial is very good that's why I'm here this year because I found it very good last year. You did a test at the beginning of each tutorial and that was brilliant it was 5 questions and you had 5 minutes to do it on the previous tutorial and you had to learn it backwards to be able to go in and answer it. You really had to study it well. You can ask questions any time you want. The tutorials are brilliant absolutely brilliant.

6. Have you used any resources outside of your lecture hours to help you with your understanding of chemistry?

Wikipedia I know you can't use it as an official reference, unbelievable absolutely unbelievable couldn't do it without it. Its brilliant because you put in a subject or say Helium and helium comes up and you know the way the links are embedded in it so if you read a line and its on about I don't knoe...Lewis Structure, its underlined, you click on that and you get the lewis structure its brilliant so I just study with that. I use the laptop to study rather than the books, I use the books very little its all the internet. I bought the books, well as many of them as I can but its all the internet stuff. You do have to be careful when you use that stuff but you have an idea whether its right or wrong.

7. Have you ever attended the Science Learning Centre and if so could you tell me a bit about your experience there?

I have gone to the SLC but I gave up going there, I went there last year...nice people, they know their stuff but they know their own stuff so I went down a few times and all I got was 'I'm not fully familiar with that'. It's a waste of my time, I pack up my books, get out everything when you are there ask the question and they don't have the answer. Its the same with the maths centre, I found the maths centre very good and they were brilliant at running tutorials as many extra tutorials that you needed but I stopped going in and asking specific questions because between the SLC and the MLC I just kept hitting people who weren't familiar with that particular subject but I could hear all the other lads chatting away to them, they were able to answer their questions so I ~~my~~ might have just been unlucky in that sense, but all their tutorials that they ran were great. The young people who have an interest in teaching are enthusiastic and if they are doing this bit of material they obviously know it so they can teach it you know that sort of a way.

8. Do you work cooperatively with your classmates or do you prefer to work individually and why?

I work in a group no problem but don't be yapping. When you get a group together there's always talking, 3 or 4 times I have sat down with a group this semester and its broken into conversation. We pass around notes though, say one of the lads wrote up about group 4 and group 14 elements and emailed it to us. When we do up something, there's a group of us and we just share it and then you get other stuff back. I tend to work myself at home but I can go on the phone and ask one of the lads if I'm not sure about something. I think most of us write up labs on our own.

9. How effective were the 2 phases of the intervention programme that you participated in, in terms of...

Timing-
Well we struggled big time with the mole and things in first year yeah, and solely the biggest problem was the mole. But the tutorials helped me make the links. When I see a question the first thing I do is write down my triangle which I forgot the last day. I was happy to go to your tutorials as we were told that there would be a full question on the mole on our exam and what I thought was grand if I go to the extra tutorials I won't have to do anything because an hour every Monday refreshes the mole stuff and that was ideal for me.

Meeting your needs-
It is actually fine if it doesn't correspond with what we are doing in the lectures but at the same time it was a question on the exam. He wasn't doing it in lectures he was just doing it in tutorials so it suits me down to the ground because the tutorials were very noisy.

Suggestions-
More formative assessment as I thought it was excellent. It forces you to learn it. It saves you from trying to learn a whole lot at the end and it makes you do a bit of work before each tutorial.

Student B

1. What questions from the post-diagnostic test did you find most difficult?

The ones with the percentages, just the whole thing with percentages, the percentage yield...I was just sitting down inside and thinking what way do I do it again. The maths side is catching me you know. I found the diagram question fine; I looked at it and said I wish they were all like this. I'd say I had the question done in less than 20 seconds, it is just a visual thing you know? The question on the mole I struggled with them from time to time.

2. What prior knowledge of chemistry, if any did you have coming into your course?

None but before I started the course I started reading a few books trying to get a grasp of chemistry. When I came in I had a willingness to learn. I left school after my Inter Cert and I was 16 and I never went back into a school again until I came in here 31 years later, it wasn't easy. I remember being at home nights boiling with frustration that I couldn't get stuff. What I found the hardest was not only did you not know the answer but you didn't know what question to ask to get the answer. You do get there though it does come together

3. What area in chemistry is most difficult for you?

The maths side of things is what I find the hardest by far, I was always pretty confident about it but when it comes to the chemistry it is very different. Also long questions with different parts. I find the mole questions...I'm getting there. A lot of the stuff to do with titrations and heat of reactions I find confusing I feel as though I am trying to learn a formula to do it without understanding it fully, you feel like you do a module without fully understanding it. You memorise stuff and try getting it all down on the page that day, I find that if I don't have an understanding I find it very very difficult.

4. What kind of an attitude do you have towards chemistry?

I enjoy it I would never see myself working in a lab full time I don't think I would have the patience, I don't think I would have the interest in it either. I do enjoy it; I look forward to the lectures.

5. How important is attendance at lectures, labs and tutorials?

Id always go to the lectures, the worst type of lecture is when someone goes in and reads the notes straight off and finish the class 15 minutes early. When there's nothing extra with it, you couldn't be blamed for not going some of the time.

6. **Have you used any resources outside of your lecture hours to help you with your understanding of chemistry?**

Everything, The MLC, the SLC, I live in the library when I have time to spare. Anything that's going and if I think it's worthwhile I'll take it. That's something I notice here, people are mad keen to help you.

7. Have you ever attended the Science Learning Centre and if so could you tell me a bit about your experience there?

The SLC has been instrumental, without it I don't think I would be here. They were brilliant; I could never speak highly enough of them. Every gap in my timetable I would try and go to the SLC. I would love if it was open 5 days a week instead of 3. Sometimes when you go in there, there might only be a person there for Biology and not chemistry, it's not their fault. I find them very helpful. I am more of a fan of text books if there was something that I was really stuck in I would type it in and see but I would be more inclined to open the book.

8. Do you work cooperatively with your classmates or do you prefer to work individually and why?

We work together in groups a lot, usually 3 or 4 of us that would come in Saturday or Sundays. It's brilliant, if you don't have the full grasp of it, another person might be able to help you along and between you you'll get there. I think a peer can explain in a better way, in very basic English it's explained to you. Also writing lab reports is much easier in groups.

9. How effective were the 2 phases of the intervention programme that you participated in, in terms of...

Timing-

First of all, it was an excellent class; I really found it very very helpful and beneficial. It's like a concentrated tutorial and it's as if they have moved the SLC up to a room for a certain number of people only. There's no problem if we ask you any questions through it or at the end of the class. I think the timing was fine.

Meeting your needs-

From the point of view of passing the exam I think it would be better if it followed lectures that we were doing at the time, but from the point of view of our understanding of the topic it worked. Some people just want to learn enough and get over the exam but if you are going to be doing chemistry for 4 years and you're going to need it in your job well then I think keep it the way it is. It generalises across the rest of the chemistry subjects. I think it should be something that's on the course for people, general tutorials that are compulsory, run it like a lab, you have to turn up and you have to do it

Suggestions-

I would make it compulsory and if you don't go to it you get docked marks. Maybe lecturers could coincide there lecture notes with what was being done in the tutorial it would reaffirm the material for everyone. Thanks very much for everything I thought it was really great and don't let it go!

Student C

1. What questions from the post-diagnostic test did you find most difficult?

This last question on the mole was what I found most difficult There is just too much to remember and I keep getting them mixed up. Like I was getting the percentage thing wrong yesterday and I know where I went wrong. I can see now what I was doing wrong, yesterday, I had about 10 minutes left, I looked at that and said where do I start? It was wrecking my head especially when I wasn't sure if what I had been doing all along was even right. I thought I was getting steps wrong so I left it. In an exam situation I would take it bit by bit and keep plugging away, knowing that I was probably getting half it wrong but at least a step might have been right.

2. What prior knowledge of chemistry, if any did you have coming into your course?

I was a blank slate when I came in. ..am... let me see now I had science for my Inter Certificate that's how long ago we're talking and that was it. I chose Health and Safety because at work, part of my job was to make sure people were wearing their safety shoes as well as doing the correct procedures manufacturing wise so there was an element of it in my old job so that's how I got interested in it. The chemistry is harder than I thought, a lot harder than I thought with biology you can read your way around it, with chemistry there's reading, maths there's bits of everything in it and it can be hard at times to fit all the pieces together.

3. What area in chemistry is most difficult for you?

I find the language difficult, the halogens react with whatever and I'm still thinking what are the halogens again? I get a muddled up with all the words. They start drawing diagrams and you're looking at them and thinking what's this about. The practical side of things, the labs are just done too quick, you just don't know what's going on in them. It's very hard to get anything out of them, I'm just doing the labs for the sake of it, just get some sort of an answer down. I hate when I'm doing something on the mole and then it moves to volume and molarity and then I don't know if I'm coming or going and it takes me a while to figure out what's happening. Stoichiometry is okay I can figure why it is balanced. Also my units can be all over the place.

4. What kind of an attitude do you have towards chemistry?

I can see why we need to do it but at this stage after 3 modules of it I just want to get the last module done and out of the way. After this we are doing analytical chemistry I'm not sure what it exactly entails but it is supposed to be interesting enough. We are looking at more job orientated chemistry. I would say I have a more positive than negative, in the middle I suppose.

It's something I hadn't done and its interesting but it has to be done so fast well I know that's the way with universities, when you are coming in fresh things move kind of quick.

5. How important is attendance at lectures, labs and tutorials?

I would attend all my lectures. I would keep an eye on all the lecture notes and if there was something I didn't understand in them I leave it all to the last few weeks and get the whole lot sorted together, I find if you can't understand a thing you might move onto the next part of the course and next thing what you didn't understand 2 weeks ago make sense now. In first semester, last year I spend too long trying to get everything in detail and now I realize if I sit back keep reading it, it might not all make sense but eventually it will make sense and you can move onto the next stage. That's helped me a bit. I go to all the tutorials and lectures for the simple reason if you ask me to read it at home I don't know what I am reading, if there is someone explaining it, it makes a lot more sense then. The tutorials are beneficial, the labs... I suppose can be beneficial now and again. It depends you see the practical side of it but you get to the stage where you don't know what you are doing and are just following the steps in the manual without understanding it. You get totally confused.I like the tutorials because they are more questioned based and we are going through examples not just theory, theory, theory and we are finding out what we need for certain questions. When I read a question now I draw out a diagram which shows the key points of the question and what it's asking and this helps me to pick out the important points.

6. Have you used any resources outside of your lecture hours to help you with your understanding of chemistry?

I would use web resources, I watch a lot of stuff on youtube. If I am reading I lose concentration very quickly at least if I watching something it's easier to take it in. And if you don't hear something or understand something, just stop it and go back and watch it again.I prefer the online stuff but I do read as well but when I'm reading I'm just looking down at the book and not really concentrating.

7. Have you ever attended the Science Learning Centre and if so could you tell me a bit about your experience there?

I have been to the SLC a good bit, it's quite good because if you are stuck on something in a question you can go but if you're going there expecting someone to teach your course then forget it! Last year we were kind of expecting that, now I might be there only 5 minutes get the help and go again. Maths was very tough, a lot of I felt was totally irrelevant to what out course actually is. It was difficult and we all struggled with it and put too much time into it and other subjects then suffered. What I also found was there was an overlap of some of the subjects this year other subjects would help me with parts of chemistry and vice versa chemistry helped me with say biochemistry.

8. Do you work cooperatively with your classmates or do you prefer to work individually and why?

Theory is individual work for me when it comes to doing a mole question or something like that or maybe a lab write up its always in a group. When you are stuck there's extra help there for you. When I go home then I might try the same question and would hopefully be able to get it out again on my own, I'd be happier then. Group sizes can vary, it depends for a lab write-up there might be three or four or sometimes more. We did this last year as well especially around exam time we would book a room in the library and work away together. With the mole we all have our own way of doing it, I know my own way it's the way I learned it so I stick to it. Yesterday I was even trying to think of the 2 triangles that we learned in general chemistry. Speaking to other students they might think they are doing something right and we all start copying them then and later find out they're wrong and we are all wrong then and it might be too late then to change it to the way it should be done. The people who are staying away from your tutorials will never know if they are right or wrong. That's probably the biggest problem with group work there is always that risk.

9. How effective were the 2 phases of the intervention programme that you participated in, in terms of...

Timing-

I think it suited better the way it was because that time we needed revision of what we had done otherwise the basics would have been slipping away from us. When we came into your programme it reinforces what we need.

Meeting your needs-

In terms of this phase I needed to be constantly working on the mole to grasp it. The stuff we did in lectures made sense because of the stuff we did in your tutorials.

Suggestions-

Putting up a question, us working on it for 10 minutes and then getting the right answer would be the ideal for me like what we were doing. Working with the person beside you was a help too, as we did. A bit of group work and a bit of tutoring as well. Go back to the very, very start and go through what we need to know and to build on this bit by bit. It worked well, if it was made compulsory people still won't go.

Student D

1. What questions from the post-diagnostic test did you find most difficult?
If any, the percentages ones and it's because they're too easy we don't do any work on them. I had to think about them before I did them and even doing them I wasn't 100% sure, well I was reasonable confident they had worked out. In terms of the mole and from what we have done in your tutorials, I think I have mastered it. I still wouldn't be confident on the back titrations, I need to spend a bit more time on them. I would be comfortable enough with the other questions on the test.

2. What prior knowledge of chemistry, if any did you have coming into your course?
I did chemistry in my Leaving Certificate in 1980 which is 30 years ago so I would have been familiar enough with chemistry and the mole and things and they were probably still with me. I think having leaving Certificate chemistry helped me even though it was a few years back, it wasn't my first time looking at the periodic table, it wasn't my first time looking at equations and balancing them or whatever.
I chose Health and Safety because I wanted to have a degree on my C.V. I just had a diploma on electronics from years ago and a diploma in health and safety so a degree was my next option and a degree in Health and Safety was going to be easier for me to get because I already have a diploma and I would get exemptions and I was going to be able to do it part time. I am happy with it, I find there is more work than I had anticipated. Is the course too difficult or too hard, I don't think so, if it wasn't like that it'd be undervalued.
I had a good grasp of maths coming in, it's a good experience here. The SLC is very good the tutorials are very good, there's more help there. Some people might argue that there is too much help out there. First years are well looked after this year it's cranked up a notch.

3. What area in chemistry is most difficult for you?
The part we are doing this year is inorganic chemistry and there's an awful lot in that, while we had the basics about bonding and orbitals and all that it's all coming at us now, we should have paid more attention to the basics. The different properties going down a group and across a group and what happens in different groups, the alkalis, the halogens the differences between them and things that we haven't heard of before. I find that difficult. Something that we haven't spend much time on and I would also find difficult is the Bohr Theory and energy moving electrons from one orbital to another and where to find them.
As a student I would say we could have done with a bridging module...how much spoon feeding do we need?

4. What kind of an attitude do you have towards chemistry?
I like it, I'd be a square boxes, straight lines person. I'm good at maths so would like chemistry. I would like to think I pick up the concepts easily enough. I wouldn't dread the lectures or the labs.

5. How important is attendance at lectures, labs and tutorials?
I would be a huge believer in attendance at lectures. If you equate it to the 50 minutes of lecture, if you're not there, you're probably not spending that 50 minutes studying

for the people who are trying to pick up the concepts it is much better. Thank you vey much for your help over the last 2 semesters.

Student E

1. What questions from the post-diagnostic test did you find most difficult?
Well obviously I would go for question 11. For some reason I couldn't get my head around it. Generally I'm good enough with The Mole, it's one of my better areas actually.

2. What area in chemistry is most difficult for you?
Formulas, some definitions, just trying to remember some things. It depends how often I use it (formulas) but I generally try to learn the formulas.

3. What prior knowledge of chemistry, if any did you have coming into your course?
I did Leaving Cert Chemistry. My teacher was very poor to say the least so I went for a couple of grinds. I worked a lot coming up to the pres and the Leaving certificate to bring myself up and get what I needed to get the course. I did honours.
I had originally gone with nursing but then I found out there were quite a few disadvantages in that so I changed my mind and started thinking about what I was actually interested in and I realised that I am interested in the environment.

4. What kind of an attitude do you have towards chemistry?
I like chemistry I think it's interesting but that probably helps me learn if I didn't like it I would be in trouble as there is a lot of chemistry in my course. Am... I like it it's just hard.

5. Has your attitude to Chemistry influenced your dedication to the subject?
Well if you take into consideration what we are doing now for this module it's the one subject out of the five that I have to study most for because I find it hard and I need to bring myself up in marks in it, I like it but it requires a lot of work.

6. How important is attendance at lectures, labs and tutorials?
I would advise to go to them all because even if you sat there and did nothing you might take in something. It's better to make the effort throughout the years rather than trying to cram it all near the end. I think the notes should be given out beforehand but that's really awkward for me getting the notes and having to print them out. The module tutorials are fairly good but if the module itself wasn't so advanced it'd be easier. I find writing up the lab reports the hardest as we might cover the lab material and then not meet in the lecture notes until a few weeks later.

7. Have you used any resources outside of your lecture hours to help you with your understanding of chemistry?
I went to the SLC, the internet obviously and some books. I would trust a book more but if I couldn't find what I was looking for I would go to the internet and then if I'm stuck altogether I will go to the SLC.

8. Have you ever attended the Science Learning Centre and if so could you tell me a bit about your experience there?

Am... They are pretty good they generally try to work through the problem with you. Usually I go through exam papers and if I find a question I can't do I usually mark it, continue on and then I go to the SLC and try and sort it out.

9. Do you work cooperatively with your classmates or do you prefer to work individually and why?
Predominantly on my own but occasionally in groups doing lab reports or exam papers. We don't do it that often. There is a mix of advantages and disadvantages, on the down side it is easier to get distracted but on the upside you can help each other

11. How effective were the 2 phases of the intervention programme that you participated in, in terms of...

Timing-
Well I think it was really good that they came in so early on and it was of huge benefit to me in first year.

Meeting your needs-
Your tutorials were very good it's just that they could be a little more advanced I have learned most of the basics already it'd be more the advanced stuff that I struggle with.

Things you liked about the tutorials-
I learn best on a one to one basis so small groups in our tutorials worked best for me.

Suggestions-
For first years I think its working fine I'd leave it as it is especially as a lot of them wouldn't have done chemistry before, wouldn't have a clue about the mole. For second years though the modules are much harder and much harder than general chemistry so they might be stepped up for that.

Student F

1. What questions from the post-diagnostic test did you find most difficult?
Am...Well there's a lot of kind of formulas and that to remember like no. of moles is mass over volume...I actually can't even remember them properly I usually write them down when I'm trying to remember them. Am... You have to remember a lot of formulas and then when you're doing a calculation problem if you get one thing wrong with your formula it affects all your answer and then all your answer is wrong. Am... and then like you can often make an easy mistake when you're calculating out the GMM of a molecule because you have a couple of things to add up because you have different things in the molecule. If you make a mistake in that then you have a mistake in it later on. As well then when you're doing mole calculations it's hard to understand the equations because sometimes there's different number of moles and different things in the equations so that's kind of hard and you can get mixed up in that sometimes too.

2. What area in chemistry is most difficult for you?
Am...well some of the language because I never did chemistry before so when you come in and they are talking about ions and cations and orbitals, all words that I didn't know what they were and some of them weren't explained, you don't know what they are and then mole or molarity I get mixed up between them sometimes. There're lots of words that are similar, the words that you wouldn't have heard of before and you don't really know what they mean. It's hard to understand the different meaning on them.

3. What prior knowledge of chemistry, if any did you have coming into your course?
I did Junior Cert. science, there was a bit of chemistry there in that. I didn't really like the chemistry in J.C. so I just did Biology for my Leaving Cert. So I had no L.C. chemistry so that's probably a disadvantage. Well if I had known before I did the course that I'd need L.C. chemistry maybe I would have done it but I didn't realise there would be so much chemistry in it. Maybe I should have known about that.

4. How did you cope with your General Chemistry Module last semester?
Yeah that was kind of hard because there was all new words and formulas and new definitions, yeah that was kind of tough I had to a lot of study for that.

5. What kind of an attitude do you have towards chemistry?
Am...personally it's probably negative, I don't really like it because I find it very hard I don't know I still try to study it, it does take a lot more time than some of my other subjects like I'm better at biology and microbiology and them kind of subjects but the chemistry takes more time like but I do give time to it but I don't enjoy having to give time to it really.

6. How important is attendance at lectures, labs and tutorials?
Well labs are compulsory so you would fail if you didn't go to them so you have to go to them but am the tutorials are very good but the lectures are good too but you can get the lecture notes without going to the lectures so sometimes you could read them and you might know as much as the lecturer but the tutorials are better sometimes because you actually talk through the stuff and explain it so I find them better than the

lectures but I still go to all of them as I don't really know much chemistry so I think I should go to them to try and learn as much as I can. I find the labs really hard; the lab write ups are really hard because you don't know what to write. The labs are so rushed you know even if you ask the demonstrators they can't tell you the answers but like am...sometimes then you do the lab and maybe three weeks later you might see something that should have been in your lab report in the lecture so they are not really timed at the right time, if they were done together, what's done in the lab and the lecture it would be easier to understand them but the way its done now its harder to understand the labs. You just go in and I'm usually copying off the group beside me, what technique they're doing. I don't copy the lab reports.

7. Just picking up on a point you made there about the availability of lecture notes, would you prefer if they weren't available?
I think skeleton notes are a good idea, that makes you go to the lecture if some of the notes are there you have more of a chance then to listen to the lecturer and write down what they are saying but if you had to write down everything they were saying you would never be able to write that fast and then if the lecturer was to give you everything you would probably less inclined to listen to him so that probably the best way, to give half notes and fill them up because sometimes if the lecturer doesn't say anything more than what's on the lecture notes that isn't very helpful you want the lecturer to explain what's on the notes too.

8. Have you used any resources outside of your lecture hours to help you with your understanding of chemistry?
Am...I use Google a lot for some of the words because I don't know what they mean and they come up in wikipedia so that's kind of a help am... and there's a book in the library, it was on the list the lectures gave us I use that sometimes, but the book is really big and there's loads of information in it and it's hard to know how much of it I need to know because I wouldn't be able to know it all. So I use the book sometimes and I use the internet but really I find the tutorials helpful too. They were good because they were covering the stuff we need to know. There was a lot on the mole and I actually think I understand it a bit better now like how to calculate values and molarity of things so I have a better understanding but like what I would think would be helpful if there were more tutorials on the other chemistry modules and other chemistry topics because we are doing analytical chemistry and organic chemistry as well and them two are really hard too and there's loads of other stuff to learn in them too.

9. Have you ever attended the Science Learning Centre and if so could you tell me a bit about your experience there?
I only went there once because I play camogie, I usually have matches on a Wednesday evening when the centre is open so I don't usually make it but am... I did go once, I don't know I just went there to find out about a lab report, they don't give you the answers, well I know they're not supposed to give you the answers but they did explain the calculations that should have been done so it did help that way but maybe I should have gone there more often and it would have been more of a help.

10. Would you say it is an effective resource to have in the college for people who don't have L.C. chemistry?

Yeah it is and I suppose if there weren't tutorials like the ones about the mole I would have to go to the SLC more because I wouldn't have as much of a chance to learn and understand it.

11. How effective were the 2 phases of the intervention programme that you participated in, in terms of...

Timing-

Well it wasn't too soon then because I didn't have L.C. chemistry so that first General Chemistry module was very hard. It was all the new words and I didn't get a chance to study some of it until near the end of the semester. I had a lot to study when it came to it. If the tutorials had started earlier it would give me a head start and a better chance to understand chemistry because now I feel like I'm trying to catch up and that I will never actually get the full understanding of it.

Meeting your needs-

It was good that it was basic things but it would be better if it was going towards the exam because they're sill some topics for my exams that I feel that if I got more tutorials on I could understand them better. I think it would be useful if the tutorials went with what I was studying because if you are learning everything a couple of times you would understand it better so even though it was good I think it would be better if it coincided with the exams that I was doing. I think then more people would be interested then and more people would go to it if they thought it was linked.

Things you liked about the tutorials-
Am... well they were good because like sometimes at the start of the classes we'd have a small little test and examples of questions we did the week before that would make you study because you would know they were going to come up so you would look over what you did the week before so it'd be fresh in your head before you went in and then because you would correct the test in the class or your peers would correct them then you find out immediately if you did it right or wrong. It was great when you found out you did something right because you wouldn't have been able to do it the week before, it was good to see you were answering then and like because there were only small numbers in the tutorial, I felt I was able to ask you questions because in a lecture, there's always loads of people in our lectures you're not going to ask a question because nobody asks questions but in the tutorial you can ask questions to make sure you understand it and that was a help and there were lots of resources like the small quizzes and you could find out if you were right or wrong, you could do them online. The powerpoints were available online as well and they were really helpful because there were animations on them and you could click on them it made it really visual so you could understand the chemistry of it better.

Suggestions-
I definitely think you should make it earlier and maybe if you made it compulsory more people would go. I think maybe the people who didn't go didn't realise how helpful they might have been if they had know now they might be sorry they didn't go so if you made it compulsory, if you got marks for going I think people would go so like we get marks for going to labs so if you got another 20% or 10% for going to the

tutorials more would go and everyone would learn and understand it a lot better so that would be a help. If the tutorials were more based on what we do in exams rather than just some topics even though they were good but if they went with what we were learning in the module they would be more helpful. The tutorials were helpful and I hope they are going on again next year because they are giving me a chance to learn chemistry. It'd be hard to learn chemistry with just lectures, I'd miss not having the tutorials.

Appendix G

Conference Abstracts

Conference Poster

Conference Paper

Peer-reviewed Paper

- **ECRICE (European Conference on Research in Chemical Education) Pedagogical University, Krakow, Poland. 4-9 July 2010**

Retaining Weaker Students in Undergraduate Science Programmes

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Background, Framework and Purpose

Since the eighties, there has been an increasingly significant problem with students dropping out during their third level education. The Irish government's expansion policy on education has resulted in much higher numbers pursuing higher education than ever before, with over 60% of school leavers progressing to third level education in 2009 (Forfás Expert Group on Future Skills Needs, 2009). In addition, the current economic climate has led to an increase in the numbers of students choosing to stay in third level education.

While the large numbers are seen as progressive and an improvement in the education system, it does lead to the problem of a very diverse group of students in higher education. (Childs & Sheehan 2009; Darmody & Fleming 2009) It is of vital importance with groups of wide ability that we ensure that the weaker students do not get lost or left behind. This pilot study is an attempt to increase retention amongst weaker students in undergraduate science programmes.

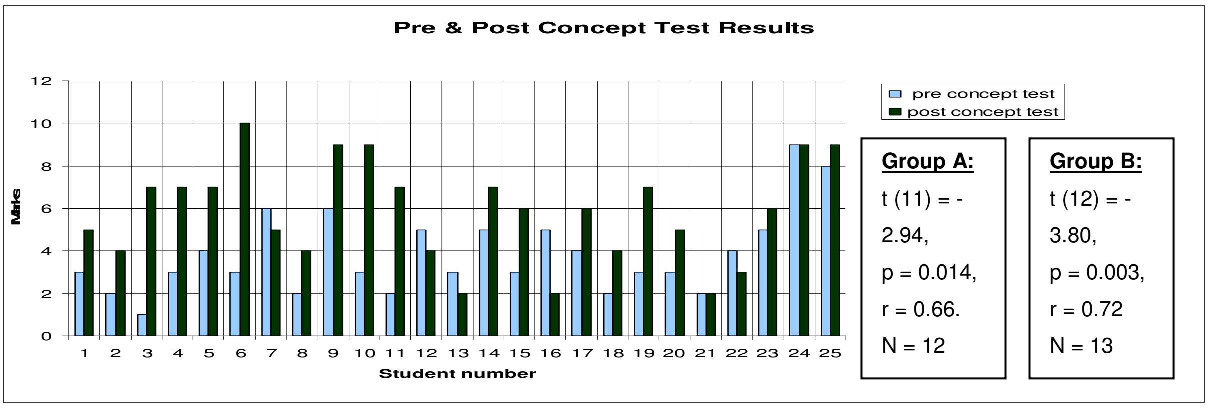
Method

A pilot intervention programme was designed for two groups of students, who have previously been identified as weak, in the first semester of the 2008-09 academic year. This programme lasted 9 weeks, consisting of tutorials in basic chemistry, linked to a chemistry module in Inorganic chemistry. This was an optional programme offered to the students, which meant we were only able to measure the performance of those who took both the pre- and post-tests. A pre- and post-diagnostic test of chemical concepts and misconceptions was designed and administered in the first and last tutorial session. The test also included an instrument measuring student attitudes and confidence towards science. The attitude/confidence tests used a Likert instrument. The pre- diagnostic concept tests were used to design the intervention programme in order to meet the students' specific needs. The students were taken in small class groups, rather than the larger lecture groups.

The same intervention programme was repeated in the first semester of the 2009-10 academic year for the equivalent second-year student groups.

Results

Figure 1: Comparison of Pre- and Post-test results for groups 'A' and 'B'



The results based on the first intervention show, on average, a positive trend in both conceptual understanding and confidence levels. Figure 1 shows that 76% of students in both groups who did both tests improved in their post-diagnostic test performance, indicating that for the vast majority of the class the programme was beneficial. The majority of those who improved (72%) had good attendance records.

The performance of these two groups has been evaluated in the final examination for the Inorganic chemistry module, compared to the equivalent groups in the previous academic year, 2007-08. From this analysis we have seen an improvement in the groups overall performance. Students in group 'A' who participated in the intervention programme had higher grades ($M = 47.64$, $SE = 2.29$) than those who did not participant in the intervention programme ($M = 38.35$, $SE = 5.79$). This difference was not significant $t(23) = 1.50$; however it did represent a medium size effect ($r = 0.3$).Those in group 'B' who took part in the intervention programme had better grades ($M= 33.29$, $SE = 2.17$) than those who did not take part in the intervention programme ($M= 26.45$, $SE = 1.40$). This difference was considered to be significant, $t(22) = 2.64$. A medium -large size effect was also noticed ($r = 0.49$).

Due to circumstances outside of our control, only pre-diagnostic test results could be collected for the second intervention programme. This raises the problem of poor attendance and also the voluntary nature of the tutorials. From the pre-test results, these two groups of students are showing the same patterns of misconceptions as previous year's groups.

Conclusions and Implications

The results of the first intervention programme were positive. The examination results of students who undertook this programme were better than those in previous years. However, this was an optional programme and while the results are encouraging, poor attendance in both the main module and in the intervention programme clearly affect the results, as was the case with the second intervention programme. Many students who attended some of the nine week programme in the first intervention could not be assessed as they did not attend both pre- and post-test sessions. This programme successfully improved, not only chemical understanding, but also students' attitudes and confidence.

We intend to implement a longer intervention programme for the same two groups of students in their first year of study, as well as for first year students who have not previously studied chemistry in the 2010 semester. It is intended that the intervention programme will start earlier in the semester to help combat poor attendance as the students approach examination time. The new programme will also run for two semesters instead of one. The planned intervention tutorials will involve blended learning, including a combination of face-to-face teaching and learning, as well as online resources and also elements of formative assessment.

By using a variety of pedagogical techniques it is hoped that students from these groups will be equipped with the basic chemical understanding that they need for their undergraduate programmes of study, resulting in greater retention.

Keywords: Retention of students, Third level students, Chemical Education, Diagnostic Testing, Chemical Misconceptions

- **ViCE (Variety in Chemistry Education)**
  Loughborough University, Leicestershire, U.K. 2-3 Sept 2010

Retaining Weaker Students in Irish Undergraduate Science Programmes

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The increase in the percentage of Irish students entering third level education means that many students choosing science programmes do not have an adequate foundation in science.
In order to increase retention amongst weaker students in undergraduate science programmes, a pilot intervention programme was designed for two groups of students previously identified as weak. This programme lasted 9 weeks, consisting of tutorials in basic chemistry. A pre- and post- diagnostic test of chemical concepts and misconceptions was designed and administered. The tests also included an instrument measuring student attitudes and confidence towards science. The pre- diagnostic concept tests were used to design the content of the intervention programme to meet the students' specific needs. The students were taken in small class groups.

The results of the pilot intervention programme ran in 2008-9 were positive. The examination results of students who undertook this programme were better than those in previous years. However, this was an optional programme and while the results are encouraging, poor attendance in both the main module and in the intervention programme clearly affect the results.. Many students who attended some of the nine week programme in the first intervention could not be assessed as they did not attend both pre- and post-test sessions. This programme increased, not only chemical understanding, but also students' attitudes and confidence.
Due to the success of the pilot project, an expanded study has been implemented in 2009-10. This includes a longer intervention programme for the same two groups of students running over two semesters and starting in the second semester of first year. The intervention tutorials will involve blended learning, including a combination of face-to-face teaching and learning, as well as online resources and also elements of formative assessment.
Some results from this expanded programme will be presented at the conference.

- **SMEC (Science and Mathematics Education Conference)**
  Dublin City University, Dublin. 16-17 Sept 2010

Due to the increase in the number of students seeking third level education, it is true to say that it has resulted in many students choosing science programmes who may not necessarily have an adequate foundation in science. This study is an attempt to increase retention amongst weaker students in undergraduate science programmes.

An intervention programme was designed for three groups of students, who have previously been identified as weak. This programme was piloted in the academic year 08/09. The positive results from the pilot, led to the expansion of this programme into a larger scale study, which began in the academic year 09/10. This revised programme lasted 9 weeks, consisting of tutorials in basic chemistry; online resources were also made available to students.
The tutorials consisted of various strategies including peer learning and assessment, problem based learning and the use of concept questions. A pre- and post- diagnostic test of chemical concepts and misconceptions was designed and administered in the first and last tutorial session. Student's performance in both the pre- and post diagnostic tests was measured. The pre- diagnostic concept tests were used to design the intervention programme in order to meet the students' specific needs and address their weaknesses.

The results of the intervention programme were positive. The examination results of students who undertook this programme were better than those in previous years. However, while the results are encouraging, poor attendance in both the main module and in the intervention programme will be accounted for in the results.

- **IOSTE Conference 2011**
  Reading, June 20-21

From Diagnosis to Cure: Retaining Weaker Students in Chemistry

Áine Regan*, Peter E. Childs, *University of Limerick, *aine.regan@ul.ie*

Background:
High drop-out rates have become significant for science-related courses in Ireland. Government's education policy has resulted in higher numbers entering higher education (currently over 60% of the age cohort). Between 2009 and 2018 the total number of full time students enrolled in higher education will increase by almost one third (Forfás 2010).
This expansion is seen as a positive step to produce an educated workforce. The larger intake leads to the problem of a very diverse group of students in higher education. (Childs & Sheehan, 2009; Darmody & Fleming, 2009). With groups of wide ability we must ensure that weaker students do not get lost or left behind. This Intervention study aims to increase retention amongst weaker students in undergraduate Chemistry courses.

Rationale:
This study addresses the following research questions:
1. What are the particular problems students have in Chemistry?
2. What are students' attitudes and confidence level in relation to studying Chemistry at third level?
3. Can a targeted Intervention Programme improve students' performance in Chemistry examinations?

Methodology:
Based on the success of a pilot programme run in 2008-09 (Childs and Hayes 2009), an expanded study has been implemented in 2009-10. This expanded study involves a two-semester Intervention Programme, starting in the second semester of first year (Phase 1) and continuing to the first semester of second year (Phase 2). The programme was developed for three groups of students (Group A, Group B and Group C), who have been identified as weak for to the following reasons: little or no Chemistry at Second Level; weak overall academic background; weak performance in previous Third Level Chemistry examinations. A pre-diagnostic test of chemical concepts and misconceptions was administered to students in the first tutorial session of each phase, including a confidence/attitude test. The test results were used to design the content of the Intervention Programme. A post-diagnostic test was administered in the last tutorial session of each Phase. Phase 1 (10 weeks) of the Intervention Programme covered basic Chemistry topics and concepts, identified as the students' weak areas. Phase 2 (9 weeks) of the Intervention programme on quantitative topics (the Mole and chemical calculations). After Phase 2, two students were selected for interview from each group, who had completed both the pre- and post-diagnostic test in both phases

Results: <u>Pre- and Post Diagnostic Test Results</u>
Phase 1:

Overall, the results in this extended Intervention Programme have been positive. For all three groups who participated in the programme, Figure 1 shows there was a significant increase in results in the post-diagnostic test compared to the pre-diagnostic test.

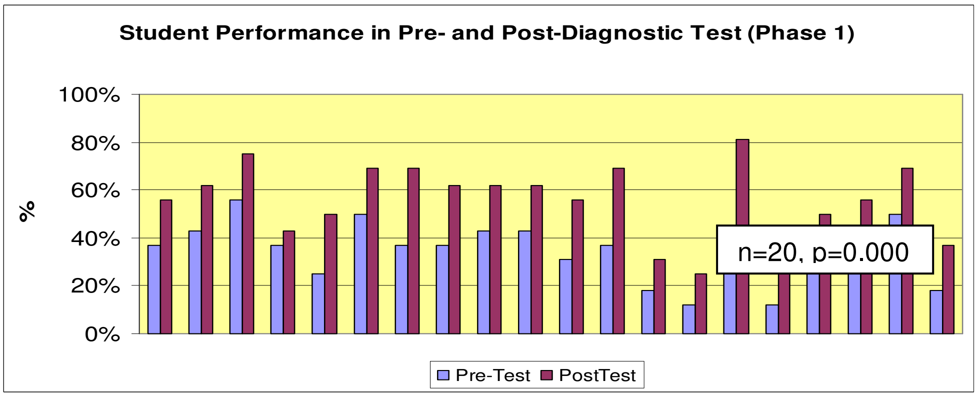


Figure 1:

Performance of students in the pre- and post- test (Phase 1).

Students in all three groups experienced, on average, slightly higher marks in the written part of their examination in their concurrent Chemistry course than those who did not take part in the Intervention Programme (Regan and Childs 2010)

Phase 2:

Initial results from Phase 2 of the Intervention Programme show positive results. For all three groups who participated in the programme, Figure 2 shows there was a significant increase in results in the post-diagnostic test compared to the pre-diagnostic test for phase 2 of the programme.

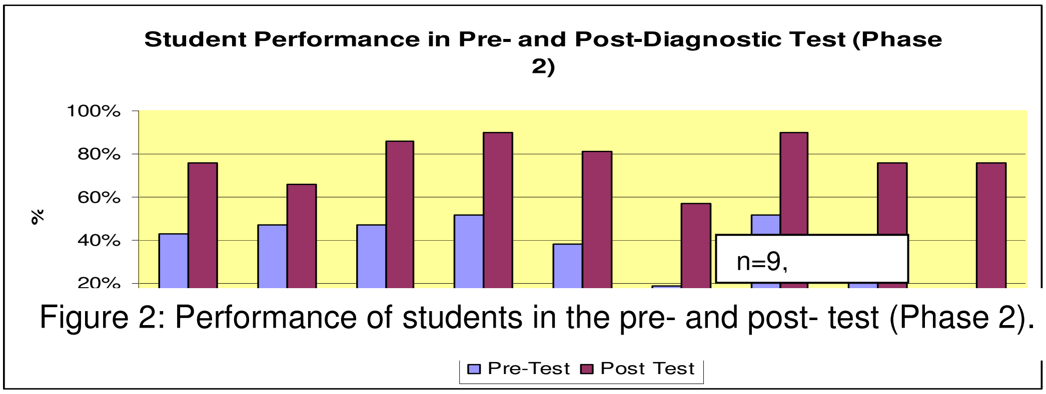


Figure 2: Performance of students in the pre- and post- test (Phase 2).

<u>Student Interviews:</u>

Initial analysis of the student interviews has shown two main themes emerging: the language of Chemistry and the chemical calculations involved in Chemistry seem to be the most difficult areas for students to comprehend.

> 'There're lots of words that are similar, words that you wouldn't have heard of before and you don't really know what they mean.' Student F
>
> 'You have to remember a lot of formulas and then when you're doing a calculation problem, if you get one thing wrong with your formula it affects all your answer' Student E

Further analysis will be carried out on the interview transcripts using NVIVO.

Conclusions and Implications:
Overall, the results of this Intervention programme are positive. It is clear from the results that taking part in the programme positively influenced students' performance in a number of ways. All of the students who completed both a pre- and post-diagnostic tests for both phases of the programme achieved higher grades in the post-test. This shows that the tutorials and web-based resources may have been successful in targeting students' specific difficulties and misconceptions in certain areas. It is also evident that students who undertook Phase 1 of the intervention programme performed better in their concurrent Chemistry module written examination. This information is not yet available for students who participated in Phase 2. In student interviews, student responses towards the Intervention Programme were very positive, but highlighted the difficulties they face with the language of Chemistry and the mathematical calculations. While these positive results are encouraging, this Intervention Programme was optional and so poor and inconsistent attendance does affect the results. Improvements noticed may be due to the self-selected nature of the sample. It is intended to conduct research into the area of student motivation to try to combat the problem of low attendance, which is a major factor in student performance.

- **Effective Learning in the Biosciences 2011**
  Edinburgh, 30 June-July 1, 2011

Chemistry is an important, underpinning subject for the Biosciences particularly Biochemistry. It often presents a hurdle to beginning students at third level depending on their Chemistry background. Identifying weak students early on and providing targeted help, as outlined in this abstract, would help overcome this problem. The increase in the number of students seeking third level education in Ireland has resulted in many students choosing science programmes for which they do not have an adequate foundation in chemistry. This study aims to increase retention amongst weaker students taking Chemistry in undergraduate science programmes. An Intervention Programme was designed for three course groups of students, who have previously been identified as weak. This programme consisted of two semesters of tutorials: Phase 1 focusing on Chemistry basics and concepts and Phase 2 focusing on The Mole and chemical calculations. The tutorials utilised various strategies including peer learning and assessment, formative assessment and the use of concept questions. A pre- and post-diagnostic test of chemical concepts and misconceptions was designed and administered in the first and last tutorial session. Students' performance in both the pre- and post-diagnostic tests was measured. The pre-diagnostic tests were used to design the Intervention Programme in order to meet the students' specific needs and address their weaknesses. The results of the Intervention Programme were positive. In both Phases, students did significantly better in the post-diagnostic test than in the pre-diagnostic test. Where possible, the performance of students who participated in the Intervention Programme was compared with the performance of students who did not participate in the Intervention Programme in their concurrent Chemistry module, and this showed a positive effect. However, while the results are encouraging, poor attendance in both the main module and in the Intervention Programme undoubtedly has an effect on the results.

Retaining Weaker Students in Irish Undergraduate Science Programmes

Áine Regan and Peter E. Childs, University of Limerick, Ireland. *Mail: aine.regan@ul.ie*

Introduction

- This study is a follow up of previous work[1] on the development of a pilot intervention programme for weak chemistry students in The University of Limerick.
- This study aims to retain weaker students in science by applying ideas from research and devising a suitable Intervention Programme.
- The intervention programme uses a combination of tutorials, formative assessment and ICT based tuition for the students.

Project Outline

Pilot Project

- 9 Week Programme given in 1 semester.
- Offered to 2 groups of students, identified as weak.
- Semester 1 Year 2 of their study.

Extended Project

- 10 Week Programme given in each of 2 semesters.
- Offered to three groups of students, identified as weak.
- Semester 2 Year 1 and Semester 1 Year 2 of their study.
- ICT based resources made available.

Setting the Scene

- The last ten years has seen a massive expansion in the numbers entering higher education in Ireland, with over 60% entering third level education in 2009 [2].
- This expansion leads to the problem of a very diverse group of students in higher education[3].
- Also, science courses at third level have significantly low rates of non-completion (22.2%)[4].
- Unless these weaker students are supported and given the time and help they need, they are at risk of non-completion of their third level studies.

Methodology

- An Intervention Programme was designed to meet the needs of the students based on the use of a diagnostic tool to identify students' chemical misconceptions and to then use this to combat these misconceptions.
- The programme involves a blended learning approach: a combination of face-to-face teaching and learning, as well as online resources and also elements of formative assessment.
- The three groups of students who participated in the Intervention Programme have been identified as weak as they have little or no chemistry studied at 2nd level, they have poor academic backgrounds and have shown a poor performance in past 3rd level exams.
- Attendance at the tutorials was voluntary.
- Participating student's performance on the concurrent chemisty module was compared with those who did not participate in the Intervention Programme.
- Students completed the pre-diagnostic test in the first tutorial session. Based on the results of the pre-test, the tutorials were designed to target the misconceptions that were identified. Students completed a post-diagnostic test in the last tutorial session.
- The diagnostic test contained questions based on basic chemical concepts. Figure 1 shows an example of a diagnostic question.

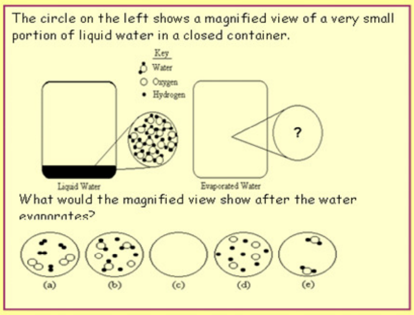


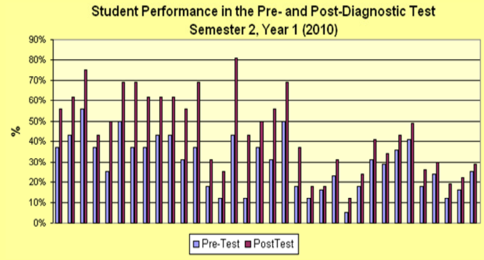
Figure 1: Concept test sample question

Acknowledgements

- Kerry County Council, Chemical and Environmental Sciences Department, NAIRTL.

Results

Pre & Post Concept Test



Group A (n=9):
$t(4) = -11.092$
$p = 0.000$
$r = 0.97$
Group B (n=13):
$t(6) = -1.135$
$p = 0.320$
$r = 0.50$
Group C (n=12):
$t(7) = -6.509$
$p = 0.000$
$r = 0.93$

Figure 2: Comparison of Pre- and Post-test results for groups 'A' and 'B'

- The results from this study have been positive.
- Overall, there was a significant difference between pre- and post-test in a positive direction (completed after students have undergone the 10 week intervention programme).
- Only students who completed both a pre- and post-Diagnostic test are considered.

Chemistry Module Performance

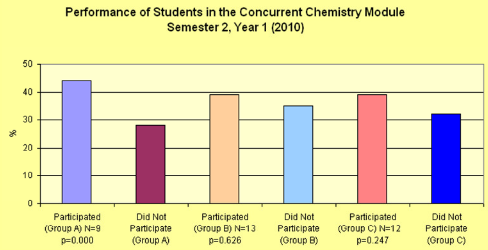


Figure 3: Comparison of Results in Chemistry Module.

- Students in all 3 groups experienced, on average (10%), slightly higher marks in the written part of their exam than those who did not take part in the Intervention Programme. This was significant for Group A.
- The mean grade of all students who participated in the intervention programme was better than those who did not.

Interaction with Web-Based Resources

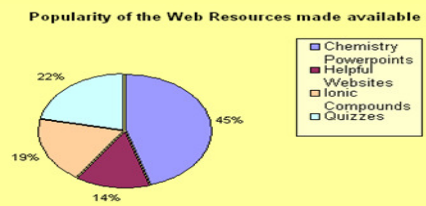


Figure 4: Activity of availability of web resources

- In total, 669 visits were made to the web site during the Intervention Programme.
- PowerPoint presentations were the most popular resource.
- These included visual animations and also examples that the students worked through during the tutorials.

Conclusions

- The results of this intervention programme are positive.
- Students' results (Group A & C) in the Post-Diagnostic Test were significantly higher than in the Pre-Diagnostic Test after taking the 10 week programme.
- The examination results of students who undertook this programme are slightly better than those who did not participate in the programme and this was significant for Group A.
- Poor and inconsistent attendance at the tutorials affected the results.

Future Work

- This Intervention Programme will be continued over a second semester, starting in September 2010.
- For this phase, it is intended to develop student workbooks which will be used during the tutorials. This is funded by a NAIRTL Grant.
- An interactive classroom response system will be used leading to more formative assessment.
- Interviews with selected individual students will be carried out.

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IOSTE Conference Paper

From Diagnosis to Cure: Retaining Weaker Students in Chemistry

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Abstract
The expansion of higher education in Ireland since the 1980's has led to a particularly diverse group of students, coming from different backgrounds with varied prior learning experiences. This includes some with little or no Chemistry background entering science courses at university. This is of considerable concern in our institution, as there are high levels of student attrition in the area of science. In order to combat this problem an Intervention Programme (Phase 1) was developed for two groups of students identified as low-achievers. This programme sought to use the students' prior knowledge and misconceptions, identified through diagnostic testing, to develop a course of tutorials for the students that specifically targeted these areas of difficulty. The programme proved to be successful and those students who participated in the Intervention Programme improved their score in the post-test. This has led to an Expanded Intervention Programme (Phase 2) being developed for three groups of students also identified as low achievers. This ran over two semesters, starting in first year and continuing into second year. Students' attitudes and confidence levels in Chemistry were assessed and student interviews were carried with two students from each group. This allowed us to probe further the students' thinking and their attitudes towards Chemistry. The results are encouraging, but poor and inconsistent attendance in both the main module and in the Intervention Programme have affected the results.

Introduction

The education system in Ireland is rapidly changing. Like many other countries it is experiencing a surge in the number of students taking up third level education. (Hailikari and Nevgi, 2010; Gou and Cao, 2009) Since the 1980's the Irish government has put a major emphasis on the higher education system, in an attempt to boost the knowledge economy and to attract foreign investment with a highly educated workforce. In an attempt to create equal access to higher education, and to boost these numbers, the government removed third level fees in the mid 1990's. This has brought about considerable expansion in third level education. Currently over 60% of the school leaving cohort enrol in higher education courses. Ireland is in the aftermath of the 'boom' years and the Celtic Tiger phenomomen and one result is that more young people are continuing on with their education, while many older people are returning to education. Today in Irish society having a degree has become the 'norm' and Ireland has one of the highest levels in the European Union (EU) of graduates in the workforce. There are high levels of unemployment at present and many of those who are unemployed are using it as an opportunity to return to third level education and to retrain. This study evolved from a need to cope with the higher numbers and greater diversity of students entering science courses at third level institutions, with the aim of preventing high levels of student attrition among those who are unprepared and unqualified.

The structure of the Irish education system

The structure of the Irish eduction system is shown in Figure 1.

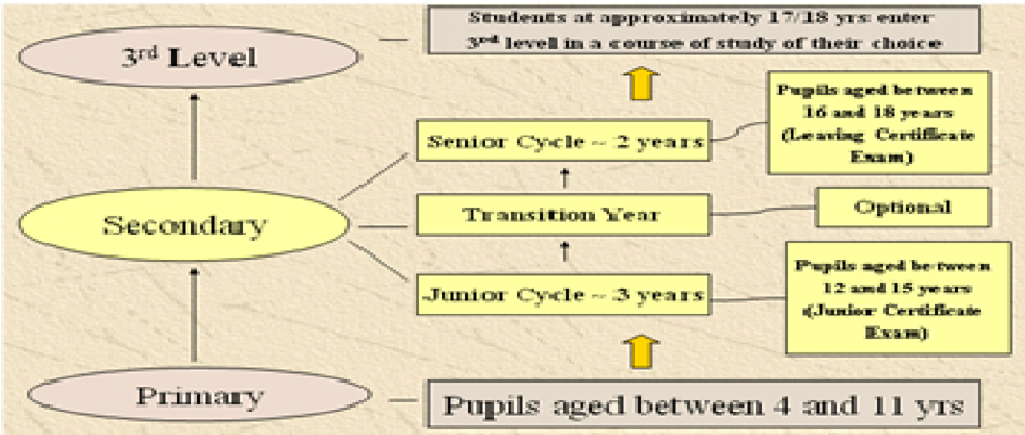


Figure 1 The structure of the Irish education system

Pupils begin their formal education aged 4/5 years in the primary cycle. This lasts for eight years, six of which are compulsory, and primary pupils have had compulsory science within the primary curriculum since 2003 and thus current undergraduate students would not have experienced it. Pupils usually finish their primary schooling aged 11/12 and enter the first three years of second level. This is known as the Junior Cycle, and science is not compulsory at this stage of the pupils' education. Ireland is one of the few countries in Europe not to have compulsory science at any stage of second level schooling. This means that the pupils' experience of science is dependent on the type of school that they attend, with the lowest levels of provision of junior science being in single sex girls schools. The Junior Cycle culminates in the first state examination, the Junior Certificate. Once pupils have finished the Junior Cycle they have the option to take the Transition Year. This is an optional extra year in second level which is curriculum-free and offers an opportunity for personal growth, development and maturity. Just over three-quarters of schools offer the Transition Year, and just over half the pupils take it. If pupils decide to take this year they can then progress on into the Senior Cycle afterwards. If students do not take the Transiton Year they can proceed straight into the Senior Cycle. Over 80% of Irish students proceed to the Senior Cycle. The Senior Cycle lasts two years and concludes with another state examination, the Leaving Certificate. Five science subjects are offered: Agricultural Science, Biology, Chemistry, Physics and Physics & Chemistry. The results of this examination will determine whether pupils can enter a third level institution to pursue a course of their choosing. In the Leaving Certificate students may take as many subjects as they wish, with most taking 7 subjects. The only compulsory subject that students must take for the Leaving Certificate is Irish, however, the vast majority of schools have made it compulsory to take English and Mathematics also, as entry into a third level institution without these subjects is almost impossible. As Childs (2006) noted, this is one of the strengths of the Irish education system, with over 90% of candidates taking mathematics for their Leaving Certificate. All subjects offered in Senior Cycle can be taken at two levels, higher level and ordinary level. There is a third option for pupils who are particularly weak in Mathematics and Irish, and this is the foundation level, though taking mathematics at foundation level excludes pupils from most forms of third level education. Higher level mathematics is typically taken by ~16% of the cohort for Senior Cycle. There is poor uptake of the physical sciences at Senior Cycle, with a typical uptakes ranging from 12 – 14 % for Physics and Chemistry. This is not the case for the biological sciences, with over 50% of the cohort taking this subject at Leaving Certificate level (Childs, 2010).

Each pupil receives points based on their six best subjects after they have completed their Leaving Certificate examinations. An A1 grade in a higher level paper can earn a pupil 100 points and a D3 grade earns 45 points. A maximum of 600 points can be achieved through the 6 subjects. (See Childs, 2010 for further details.) Based on their grades these points are then used to get into a third level course.

Ireland has a two-tier third level system with Science courses being offered in both universities and Institutes of Technology. University honours degree courses in Science start from as low as 300 points, with the equivalent courses starting from 205 points in Institutes of Technology. However, most science courses at Universities start from 350 points upwards, depending on the particular course and the institution. Courses with a higher demand, such as medicine, pharmacy and law, can start from over 500 points, with most needing over 550 points for entry. Science courses are less popular and attract weaker students on average than these professional courses.

Course entrance points are determined each year through a supply and demand system adminstered by the Central Applications Office (CAO). Essentially the points required are based upon the number of student places and the demand for these places. Therefore the number of points that one needs to be accepted into a third level degree programme does not necessarily reflect the difficulty of the course, rather, its popularity. Points for entry into courses in third level institutions change from year to year depending on demand, so that in 2010, for example, points rose for most courses due to higher demand. The Leaving Certificate examination results, third level applications and offers of course places from the third level institutions are all processed through the Central Applications Office (www.cao.ie).

Higher education in Ireland

"Higher education in Ireland has long played a significant role in underpinning government policies to promote economic growth." (Royal Irish Academy, 2009, p.3) In particular the last ten years has seen the largest increase in numbers with over 60% of 17-18 year olds now entering higher education, with the stated government goal being to reach 72% by 2020. (Higher Education Authority, 2008)

In an attempt to boost the knowledge economy and enhance the supply of graduates in science, mathematics, and engineering, the government has encouraged Universities and Institutes of Technology to increase substantially the number of undergraduates places in science. (Royal Irish Academy, 2009) Undergraduate science courses accounted for 13% of all undergraduate enrolments, with universities accounting for 60% of these. (Royal Irish Academy, 2009)

Significantly, this expansion in third level education has left us with a very diverse group of students. (Childs and Sheehan, 2009; Darmody and Flemming, 2009; Royal Irish Academy, 2009) Zeegers and Martin (2001, p.35) note, *"gone are the days when university classes contained only highly selected students, with present day classes now containing students with a more diverse range of acadamic skills, past teaching and learning experiences, prior knowledge, approaches to learning and expections of the tertiary experience"*. A consequence of increased participation rates in higher education both in Ireland and internationally has been an increase in student failures and student attrition. A study for the Irish Higher Education Authority (HEA) on course completion (Morgan *et al.*, 2000) noted that Irish students tend to have better third level completion rates than their European counterparts. The result of this combination of issues is that Irish third level institutes have been led to look closely at the subject of retention, identifing *"retention, completion and student withdrawal as important issues to be addressed"* (Moore, 2004, p1)

Third level Science

Science courses at third level in Ireland are facing a particular problem. These courses, like others of their kind across Europe, experience a high level of attrition among students. Science and Mathematics courses across Europe have lower completion rates than other courses, such as Arts and Law. This is also true for Irish courses, with these courses having significantly higher rates of attrition (22.2%) in comparison to courses such as Law (7.1%) (Moore, 2004; Flanagan and Morgan, 2004). A number of factors are involved in these low levels of completion. As mentioned previously there are low numbers taking the physical sciences and higher level mathematics at school. This leads to many students who are ill-equipped and underprepared to take a science course at third level. This is partly due to the fact that students who enter third level science courses are not always required to have taken a relevant science subject for their Leaving Certificate. Seery (2009) noted that "chemistry is taken by 10 – 15% of students in the senior cycle of school (Leaving Certificate) in Ireland, and therefore tertiary institutions cannot impose a prerequisite of chemistry for entry into chemistry based degrees because of the limited pool of potential applicants". However, the students who have not taken chemistry at school do not have an adequate grounding in the basics of chemistry for study at third level, where chemistry is often a required course in first year. In the early modules studied in these science courses, these students without an adequate science background are often left behind. (Childs and Sheehan, 2009; Hayes and Childs, 2010) The second issue is that there is a wider range of abilities and diversities entering higher education than in the past. Since students who enter the third level science courses are not required to have taken the relevant science subject at Leaving Certificate, this has become a crucial issue in undergraduate chemistry classes at third level. A discussion document produced by the Royal Irish Academy (2009, p.6) argued that "a student should only be accepted for a course from which there was a reasonable expectation that he or she would graduate." Currently, universities are accepting students who have achieved below the 50^{th} percentile in their CAO points score. The low levels of points required for undergraduate science courses attracts insufficiently prepared students, but may also deter many high achieving students, as they believe it to be a low status option. Many incoming students are inadequately qualified, which is a reflection of the allocation of government funding which is based on student numbers with little regard for educational performance. In addition, access programmes for non-traditional students have increased the number of underprepared students. Access programmes are in place to ensure that third level places are given to a number of students from disadvantaged backgrounds, who may get below the standard course requirements in their Leaving Certificate. There is also an increased number of mature students and the recently unemployed, who are returning to education to improve their prospects. It is clear that a number of students in university undergraduate science courses would benefit from the smaller class sizes, practical-based courses and individual attention received by students in undergraduate science courses in Institutes of Technology. Unfortunately as Talanquer and Pollard (2010, p.74) note "the first year chemistry curriculum at most universities is still mostly fact based and encyclopedic", and this is true of many Irish universities. However, in order to provide an appropriate learning environment for all students, the vast body of research on the teaching and learning of chemistry also needs to be taken into account, in order to deal with this diverse group of students and help them to make up their deficiencies and increase their chances of completion.

What we have learnt from chemical education research

There has been a vast amount of research conducted in the area of teaching and learning of chemistry over the past 40 years, which suggests that there are a number of areas to be addressed. (Bodner 1991; Gabel, 1999; Monk and Osborne, 2000; Reid, 2008; Johnstone, 2010, 2006, 1997;) Many have argued that we introduce concepts that are too abstract for students to deal with at their stage of cognitive development. (Nakhleh, 1992; Canpolat et al., 2006) Chemistry is a conceptually difficult and complex subject and students may find the various abstract concepts and ideas that they are being asked to hold within their working memory far too complicated as they are not expert enough to 'chunk' the information. Despite this research we still often present *'ideas clustered in indigestible bundles'*. (Johnstone 2010; Sheehan 2010; Chiu 2005) Studies have shown that many students are not reaching formal operational thinking as early as Piaget had originally thought, and this makes chemistry an almost intractable subject for many pupils. (Shayer and Adey, 1981; Adey, 1999; Shayer et al., 2007; Sheehan, 2010) Many students have numerous chemical misconceptions and it is widely accepted that if chemical misconceptions are not addressed, preferably early on, they will persist. (Nakhleh 1992; Schmidt, 1995; Coll and Taylor, 2001) These misconceptions are typically deep rooted and difficult to change, they must be specifically addressed. Recent work by Childs and Sheehan (2009) in Ireland has shown that the difficutlies in chemistry and student misconceptions persist into third level, because they have never been adequately addressed. Some of the issues raised by chemical education research that need to be addressed in teaching chemistry at second and third level are:

- Chemical misconceptions held by students
- Cognitive level of students
- Memory overload
- Poor transfer of mathematical skills
- Weak linkage between theory and practical work
- Poor prior knowledge
- Overloaded curricula
- Poor visualisation skills
- Language problems

The rationale behind this study

The nature of the issues currently being experienced in third level institutions in Ireland has created a problem in teaching chemistry. All of these issues were being keenly experienced in our institution, a University in the mid-west of the country. We had noticed, in a 2nd year chemistry module (Inorganic Chemistry 2) that there was a failure rate of 30 – 40% at the first sitting. This module is taken by students from 5 different degree courses (A – E) with the entrance points for the courses varying from 325 – 485. The courses 'A' and 'B' accounted for 95% of the failures in the year 2007. One reason for this may be that the cut off points for these two courses are significantly lower than those of the other courses who take the module. Traditionally there is also a larger percentage of mature students in these two courses, with fewer of these students having completed Leaving Certificate chemistry, having spent years outside formal education. A large number of mature students in a class can have implications for the class as a whole, as they, typically have a more varied background than the 18 – 22 year old class cohort. (Kelly, 2005) It was decided to try and tackle this problem of high failure rates, leading to high attrition rates, for these two courses by devising an intervention programme (Phase 1). This used a diagnostic test based on the findings from chemical education research to ascertain their specific problems and then used the findings to tailor the intervention programme to their specific needs and difficulties.

Methodology

The aim was to reduce the high failure rates among these groups of students by improving their understanding of fundamental chemical ideas. The Intervention Programme was guided by the following research questions:

1. Can diagnostic tests that identify students' prior chemical knowledge and misconceptions be used to design an effective Intervention Programme?
2. Does this targeted Intervention Programme improve students' performance in the post-test?
3. Does this Intervention Programme improve students' attitudes and confidence levels in Chemistry?

We invoked Perkins's (2007) model of teaching 'smarter' not 'harder' when designing the Intervention Programme. Given that there are *'flaws in the standard approach'* (Herron, 1999, p. 3) and in order for the effects of the intervention to be sustainable, we believed that it was necessary to assess not only the students' prior knowledge, but also their conceptual understanding of some basic areas of general Chemistry, which underpin introductory courses in Chemistry, and to uncover their chemical misconceptions.

Phase 1 of the Intervention Programme was designed for the two groups of students, A and B, previously identified as low achievers, in the first academic semester of 2008/2009, during their second year of study. This was a voluntary programme, which was offered to all the students in Group A and Group B. The Intervention Programme was advertised by the students' course lecturer and through e-mail. A diagnostic pre- and post-test was designed and administered during the first and the last tutorial sessions. The questions in the test instrument were taken from various validated chemical concept inventories and general Chemistry texts (see Table 1). This allowed us to test the concepts that we felt were key to an understanding of basic general Chemistry topics, which would be covered in Leaving Certificate Chemistry and in a first year General Chemistry module.

The test also included questions measuring student attitudes and confidence towards chemistry which was based on a published instrument. These attitude tests had a six point Likert scale, with a N/A option. Figure 2 shows a sample of the statements that students had to evaluate.

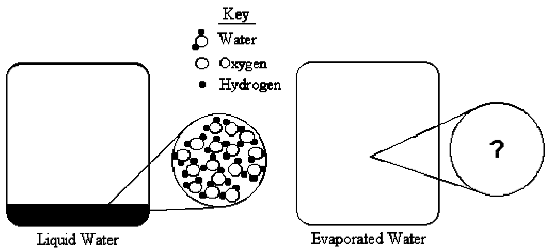
1)	Understand key concepts of chemistry and explain topics in own words
2)	Choosing an appropriate formula to solve a chemistry problem
3)	Approach a chemistry problem in a systematic manner, working step by step
4)	Determine the appropriate units for a result determined using a formula
5)	Read the procedures for an experiment and conduct the experiment without supervision
6)	Tutor another student in a first year chemistry course
7)	Apply your knowledge of chemistry to the real world

http://www.flaguide.org/tools/attitude/ntchempr.php

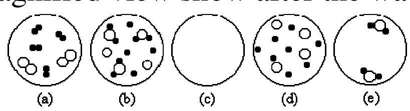
At the end of Phase 2, interviews were carried out with six students. All of the students selected had completed both the pre- and post-diagnostic test. Two students were selected from each group (Group A, Group B and Group C), one achieving a high score in the diagnostic test and one achieving a low score on the test. The interviews were semi-structured with a pre-prepared list of questions. There was also opportunity for development of the students' answers. With the students' permission all interviews were recorded and transcribed.
Despite the Intervention Programme running alongside the Chemistry module, we did not want to 'teach to' the module, but to supplement it. We were aware that many of the students lacked an adequate foundation in chemistry. This foundation, particularly in the particulate nature of matter and the mole concept, underpins many introductory chemical topics and concepts and weaknesses in this area prevent students from handling further chemistry effectively. Building the edifice of university level chemistry on a weak or defective foundation is a recipe for failure. A sample concept question from the diagnostic test is shown in Figure 3.

Concept	Questions	Source
Particulate Nature of Matter	4,5,7,8,10,15	Mulford and Robinson (2002); Sheehan (2010)
Atomic Structure	1,2,3,6,9	Mulford and Robinson (2002)
Chemical Reactions	11,13,14	Mulford and Robinson (2002); Sheehan (2010); Developed by the author
Reacting Masses and Stoichiometry	12	Developed by the author

The circle on the left shows a magnified view of a very small portion of liquid water in a closed container.



What would the magnified view show after the water has evaporated?



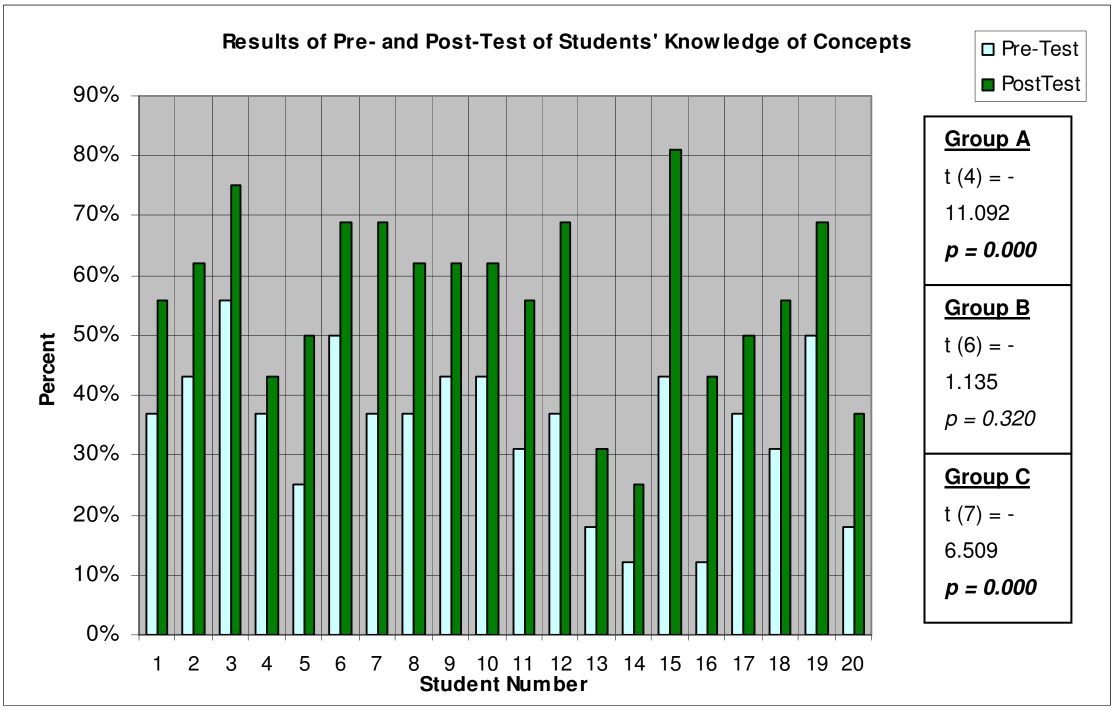
Due to the positive results of Phase 1, it was decided to run it again, but this time to expand the scope of the programme. Taking into account some of the limitations of Phase 1, we devised an Expanded Intervention Programme (Phase 2). This involved a programme running over two semesters and starting in the students' first year. Part 1 began in first year in the second academic semester of 2009-2010, following a 'General Chemistry' module, and continued as Part 2 in second year in the first academic semester of 2010-2011 (as in Phase 1). Part 1 consisted of 10 weeks of tutorials, which concentrated on basic Chemistry ideas and concepts and Part 2, which consisted of 9 weeks of tutorials, focused on chemical calculations, and in particular, the mole concept. The programme was developed for the same two groups of students (Group A and Group B) as well as a third course group (Group C), all of whom had been previously identified as low achievers. Both parts of Phase 2 were advertised in the same manner as Phase 1 at the start of each semester. For Part 1, the same pre- and post-tests of chemical concepts and misconceptions were administered in the first and the last tutorial sessions with the students as in Phase 1. For Part 2 a different diagnostic test was used, which focused on chemical calculations using the mole concept. Similarly, the results of the pre-test were used to design the science content of the programme for each group. Both parts involved a blended learning approach, which included a combination of face-to-face teaching and learning, as well as online resources and elements of formative assessment. The main limitation of Phase 2 was poor and inconsistent attendance at the tutorials and the self-selected nature of the sample, which had an effect on the results. Both phases of the intervention programme were optional for the students; attendance was voluntary, and they did not receive any extra course credits for taking the programme. We feel that this was a limitation of the programme, in that the experimental groups were self-selected. Perhaps some students who would have benefited from the programme did not choose to attend, and those who did attend were not necessarily those in greatest need. For results and analysis of Phase 1 and a more detailed analysis of Phase 2 of the Intervention Programme, refer to Regan *et al.* 2011. This paper also reported on students' performance in their concurrent and subsequent Chemistry modules.

Results and Analysis:

a) Phase 2 Intervention Programme

i) Pre- and post- test results (Part 1)

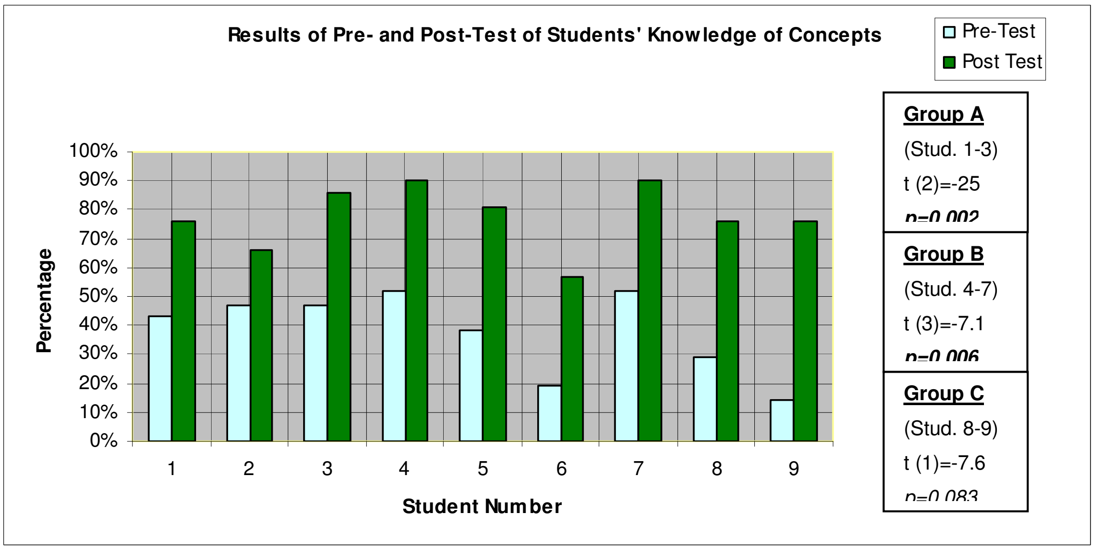
Positive results were experienced in Part 1. Figure 3 shows the results of students in both groups in the pre- and post-test.



Participants in Group A experienced significantly higher results in the post-test after taking part in the Expanded Intervention Programme (M=64.1, SE=1.89, $p = 0.000$) than in the pre-test (M=39.7, SE=2.32). Group A had the highest attendance rate during Part 1, attending 72% of the tutorials.Participants in Group B experienced higher results in the post-test after taking part in the programme (M=48.2, SE=11.9, $p = 0.320$) than in the pre-diagnostic test (M=39.6, SE=5.04), but the increase was not significant.Group B showed the lowest attendance rate for Part 1, attending 59% of the tutorials. Participants in Group C also experienced significantly higher results in the post-test after taking part in the programme (M=49.0, SE=6.75, $p = 0.000$) than in the pre-test (M=27.6, SE=5.19). Group C attended 68% of Part 1 tutorials.

ii) <u>Pre- and Post-Test Results (Part 2)</u>

Figure 5 shows the results of students in both groups in the pre- and post-test in Part 2.



The validity of these results is affected by the small numbers, but all the students showed improvement, which in some cases was very marked, and was significant for two groups.

b) Attitude and Confidence Levels (Phase 1 & 2)

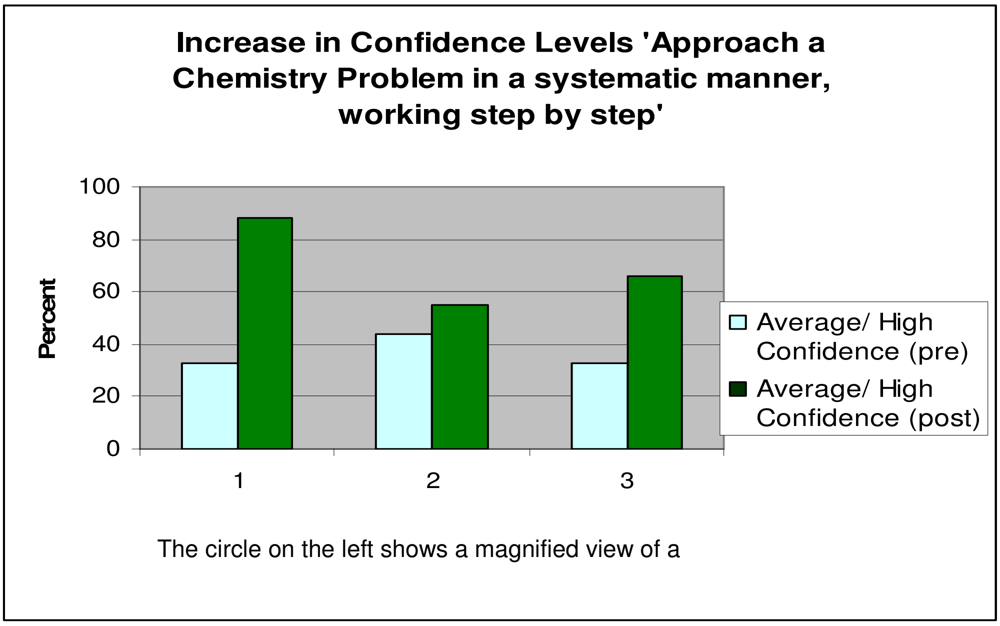
<u>Phase 1:</u>

Students' confidence to 'understand key concepts of chemistry' improved in both groups; Group A had an improvement in confidence levels and went from 50% of respondents choosing average and high, to 73% choosing these options. Group B had their confidence levels go from 50%, choosing average, to 56% choosing average and high. (A shift of one point on the Likert scale) However, paired t-tests show an overall improvement in confidence levels in both groups was not significant. Group A and Group B ($p > 0.05$).

<u>Phase 2:</u>

In Part 1, students' confidence to 'Tutor another student in a first year Chemistry course' improved in all groups; Group A had an improvement in confidence levels and went from 50%, of respondents choosing average and high, to 62% choosing those options. Group B had their confidence levels go from 30% choosing average and high, to 44% choosing these options and Group C went from 27% choosing average to 39% choosing average and high (A shift of one point on the Likert scale). However, overall improvement in confidence levels in the three groups was not significant.

In Part 2, positive results were also experienced. Students' confidence to 'Approach a Chemistry problem in a systematic manner, working step by step' improved in all groups; Group A had an improvement in confidence levels and went from 33%, of respondents choosing average and high, to 88% choosing these options. Group B had their confidence levels go from 44% choosing average, to 55% choosing average and high and Group C went from 33% choosing average to 66% choosing average and high (A shift of one point on the Likert scale). The overall improvement in confidence levels in the three groups was significant (p=0.000). Figure 6 shows an example of student responses to one particular question on the attitude and confidence test.



c) Student Interviews

The interviews carried out with the students provided an excellent insight into students' thoughts and opinions on Chemistry. This also gave an opportunity to investigate the thinking behind their responses to questions on the diagnostic test. The main themes that emerged from an analysis of the student interviews were:

1. Language of Chemistry:

Students find the language of chemistry difficult to understand.

'*There're lots of words that are similar, words that you wouldn't have heard of before and you don't really know what they mean.*' Student F

2. Chemical Calculations:

The mathematical element to chemistry was difficult for students also.

'*I don't understand the calculations, I just write down everything on the page that I know and hope some bit of it is right*'. Student E

3. Use of algorithms:

During the interviews, the students mentioned their reliance on algorithms. When probed further, students could not explain why the formulae gave them the right answer but despite that they used them to get the right answer by substituting in values.

'*I feel as though I am trying to learn a formula to do it without fully understanding it*'. Student B

'If you get one thing wrong with your formula it affects all your answer and then all your answer is wrong'. Student F

Students also spoke about their attitudes towards Chemistry: four out of the six students interviewed said they liked and enjoyed Chemistry but found it the most difficult subject studied. The pace of the lectures was also mentioned and the amount of material covered.

'It's something I hadn't done and it's interesting but it has to be done so fast. Well I know that's the way with universities, when you are coming in, things move kind of quick' Student C

'If you miss one lecture, you are totally lost. So much gets done in an hour that you feel like you will never catch up'. Student A

Conclusions and Implications:

Overall, the results of this Intervention programme are positive. The programme positively influenced students' performance in a number of ways. All of the students who completed both a pre- and post-diagnostic tests for both Phase 1 and Phase 2 (Part 1 and Part 2) of the programme achieved higher grades in the post-test. This shows that the tutorials and web-based resources have been successful to a limited extent in targeting students' specific difficulties and misconceptions in certain areas. Results of the attitude and confidence tests were positive. There was a slight increase in confidence levels in certain areas. However, the increase is only significant for Part 2. Confidence level increases could be due to a number of reasons, such as the opportunity to revisit and practice ideas students have not understood before, small class sizes, relaxed environment of tutorials, a variety of teaching strategies as well as the use of web-based resources.

In student interviews, student responses towards the Intervention Programme were very positive, but highlighted the difficulties they face with the language of Chemistry, chemical calculations and reliance on algorithms. Also, students spoke about having a positive attitude towards Chemistry and enjoying the subject. However, the attitude and confidence tests did not reflect this, indicating that even though students enjoy the subject, their confidence levels in it are not as high. Two reasons why students see Chemistry as difficult are a) the amount of material they are expected to cover and b) the rate at which it is covered in general Chemistry courses. These findings highlight the importance of conducting student interviews. They give a deeper insight into students' thinking and allow more opportunities for uncovering and discussing student problems.

While these positive results are encouraging, this Intervention Programme was optional and so poor and inconsistent attendance has affected the results. Many of the students who participated could not be assessed as they did not complete both the pre- and post-diagnostic tests. The improvements noticed may also be due to the self-selected nature of the sample. The more motivated students may have availed of the intervention programme rather than the weaker students. It is intended to conduct research into the area of student motivation to try to combat the problem of low attendance, which is a major factor in student performance. If motivation levels can be increased among the students, this may lead to an increase in their confidence levels and performance in Chemistry.

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The use of an intervention programme to improve undergraduate students' chemical knowledge and address their misconceptions

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The expansion of higher education in Ireland since the 1980's has led to a particularly diverse group of students, coming from different backgrounds with varied prior learning experiences. This includes some with little or no Chemistry background entering science courses at university. This is of considerable concern in our institution, as there are high levels of student attrition in the area of science, and in order to combat this problem an Intervention Programme (Phase 1) was developed. This programme sought to use the students' prior knowledge and misconceptions, identified through diagnostic testing, to develop a course of tutorials for the students that specifically targeted these areas of difficulty. The programme proved to be successful and those students who participated in the Intervention Programme improved their score in the post-test and showed an improvement in their concurrent and a subsequent Chemistry module, compared to students who did not participate. This has led to an Expanded Intervention Programme (Phase 2) being developed. This ran over two semesters, starting in first year and continuing into second year. This paper discusses the background to these programmes, the use of diagnostic testing in designing the intervention and their initial outcomes.

Keywords: chemical education; chemical misconceptions; higher education; diagnostic testing; student retention

Introduction

The education system in Ireland is rapidly changing. Like many other countries, Ireland is experiencing a surge in the number of students taking up third level education. The Irish government's expansion policy on education has resulted in much higher numbers pursuing higher education than ever before; currently 65% of the age cohort (Department of Education and Skills, 2011). It is estimated that between 2009 and 2018 the total number of full time students enrolled in higher education will increase by almost one third, going from 155,000 to almost 204,000 (Forfás, 2010). While the large numbers are seen as progressive and an improvement in the education system, it does lead to the problem of a very diverse group of students in higher education, both in ability and educational background (Childs and Sheehan, 2009; Darmody and Fleming, 2009). The Leaving Certificate Examination is the final examination in the Irish Second Level School System (see Appendix). Chemistry is not a required subject for entering a science course, as usually any science subject will suffice in addition to mathematics.

In 2010, just under 14% chose to study Chemistry for their Leaving Certificate Examination (Childs, 2011). Many of the students do not have an adequate grounding in the basics of Chemistry for studying it in higher education, where Chemistry is often a required course in first year. In the early modules studied in these science courses, students without an adequate background in Chemistry are often left behind (Childs and Sheehan, 2009; Hayes and Childs, 2010). There is a wider range of abilities and diversity in educational background entering higher education than in the past. There is also an increase in the number of mature as well as non-national students joining them, with few of these students having completed Leaving Certificate Chemistry or an equivalent course. The problem found in Ireland, of greater numbers of unprepared students entering higher education, is mirrored in the UK (The Royal Society, 2011).

There has been a vast amount of research conducted in the area of teaching and learning of Chemistry over the past 40 years, which suggests that there are a number of areas to be addressed (Johnstone, 1997, 2006, 2010; Bodner, 1991; Gabel 1999; Monk and Osborne, 2000; Reid, 2008). Many have argued that the concepts introduced in school are too abstract for students to deal with at their stage of cognitive development (Nakhleh, 1992; Chiu 2005; Canpolat *et al*., 2006; Sheehan 2010). Chemistry is a conceptually difficult and complex subject, and students may find the various abstract concepts and ideas that they are being asked to hold within their working memory far too complicated, as they are not expert enough to 'chunk' the information. Despite this research, we still often present *'ideas clustered in indigestible bundles'* (Johnstone, 2010). Studies have shown that many students are not reaching formal operational thinking as early as Piaget had originally thought, and this makes Chemistry an almost intractable subject for many pupils (Shayer and Adey, 1981; Adey, 1999; Shayer *et al*., 2007; Sheehan, 2010). Many students have numerous chemical misconceptions, and it is widely accepted that if these are not addressed, preferably early on, they will persist (Nakhleh 1992; Schmidt, 1995; Coll and Taylor, 2001). These misconceptions are often deep rooted and difficult to change, and they must be specifically addressed. Recent work in Ireland by Childs and Sheehan (2009) has shown that the difficulties in chemistry and student misconceptions persist into higher education. Some of the issues raised by chemical education research that need to be addressed in teaching chemistry at all levels are:

- Chemical misconceptions held by students
- Cognitive level of students
- Memory overload
- Poor transfer of mathematical skills
- Weak linkage between theory and practical work
- Poor prior knowledge
- Overloaded curricula
- Poor visualisation skills
- Language problems

All these issues were being keenly experienced in our institution, a university in the mid-west of the country. For example, in a second year 'Inorganic Chemistry' module there was a failure rate of 30-40% at the first sitting. It was decided to try and tackle this problem of high failure rates by devising an Intervention Programme, which was introduced in parallel with the second year 'Inorganic Chemistry' module. A diagnostic test (based on findings from chemical education research) was used to ascertain their specific problems, and the findings were used to tailor the programme to their needs. This was a non-compulsory programme which was aimed to help two particular groups of students identified as low achievers (Group A and Group B), by attempting to improve their knowledge and understanding of basic ideas in Chemistry. Groups A and B were selected because they had: the highest number of failures in the 'Inorganic Chemistry' module; they had lower university entry points; they included larger numbers of mature students, and previous experience had shown these two groups struggled with other courses in Chemistry. Based on the positive results from the initial intervention (Phase 1), it was decided to expand the programme over 2 semesters, starting in first year and continuing into second year (Phase 2).

Methodology

a) Phase 1 intervention programme

In light of the issues that were raised by high failure rates in the second year 'Inorganic Chemistry' module, it was decided to develop an Intervention Programme, to run concurrently with the module in the first semester of second year for Groups A and B. The aim was to reduce the high failure rates among these students by improving their chemical understanding. Phase 1 was guided by the following research questions:

- Can diagnostic tests that identify students' prior chemical knowledge and misconceptions be used to design an effective Intervention Programme?
- Does this targeted Intervention Programme improve students' performance in the post-test?

- Does attendance at the Intervention Programme make a difference in the students' overall performance in their concurrent chemistry module?

- Does the effect of the Intervention Programme continue in subsequent chemistry modules?

We invoked Perkins' (2007) model of teaching 'smarter' not 'harder' when designing the Intervention Programme. Given that there are *'flaws in the standard approach'* (Herron, 1999, p. 3) and in order for the effects of the intervention to be sustainable, we believed that it was necessary to assess not only the students' prior knowledge, but also their conceptual understanding of some basic areas of general Chemistry, which underpin introductory courses in Chemistry, and to uncover their chemical misconceptions.

The Intervention Programme was designed for the two groups of students, A and B, previously identified as low achievers, in the first academic semester of 2008/2009, during their second year of study. This was a voluntary programme, which was offered to all the students in Group A and Group B. The Intervention Programme was advertised by the students' course lecturer and through e-mail. A diagnostic pre- and post-test was designed and administered during the first and the last tutorial sessions. The questions in the test instrument were taken from various validated chemical concept inventories and general Chemistry texts (see Table 1). This allowed us to test the concepts that we felt were key to an understanding of basic general Chemistry topics, which would be covered in Leaving Certificate Chemistry and in a first year General Chemistry module. Despite the Intervention Programme running alongside the Chemistry module, we did not want to 'teach to' the module, but to supplement it. We were aware that many of the students lacked an adequate foundation in chemistry. This foundation, particularly the particulate nature of matter and the mole concept, underpins many introductory chemical topics and concepts, and its lack prevents students from handling further chemistry effectively. Building the edifice of university level chemistry on a weak or defective foundation is a recipe for failure. It was decided to address basic chemical prior knowledge and concepts because of the students' limited background in Chemistry and our own experiences in teaching this cohort of students and others like them. The diagnostic test contained a total of 15 questions, some of them multiple choice and some free response. Some questions used words only and some involved illustrations. Questions were designed to ascertain the students' knowledge and in some questions, like the one shown in Fig. 1, to identify their misconceptions. The free response questions were included to enable us to investigate students' thinking behind the response to questions, and to examine their approach to the question. The test also collected information on the student's prior experience in chemistry and mathematics.

Concept Area	Questions	Sources of questions
Particulate nature of matter	4,5,7,8,10,15	Mulford and Robinson (2002); Sheehan (2010)
Atomic structure	1,2,3,6,9	Mulford and Robinson (2002)
Chemical reactions	11,13,14	Mulford and Robinson (2002); Sheehan (2010); Developed by the author
Reacting masses and stoichiometry	12	Developed by the author

Table 1: Areas tested on pre- and post-test

If we take a closer look at the question on 'Phase Change' illustrated in Fig. 1, it is clear that it was a very poorly answered question, (Fig. 2), with only 11% of students choosing the correct answer. When we look at the answers in detail, option D was the most popular choice of the students (Table 2). This indicates that they believe when water evaporates, the water molecules separate into hydrogen and oxygen atoms. This is an example of a common misconception for students as it was the case for both Phase 1 and Part 1 of Phase 2. The tutorials were designed using the information obtained from the pre-tests on common student misconceptions and weaknesses in their prior knowedge.

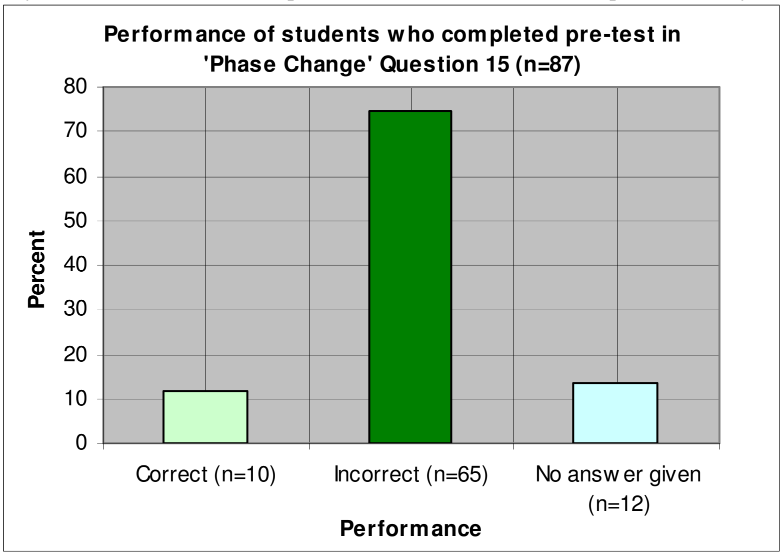


Fig. 2: Performance of students in test question 15 shown in Fig. 1

Topic: Phase Changes at Particulate Level						
	A	B	C	D	E (Correct ans.)	*Not Answered*
Phase 1 (n=34)	21% (n=7)	6% (n=2)	18% (n=6)	32% (n=11)	6% (n=2)	*18% (n=6)*
Part 1 of Phase 2 (n=53)	*9% (n=6)*	*13% (n=7)*	*22% (n=12)*	*26% (n=14)*	*15% (n=8)*	*9% (n=6)*

Table 2: Percentage of options chosen by students in test question 15 shown in Fig. 1

The students were kept in their course groups and each group was taken at different times for their tutorial sessions. It was decided to take this approach, as the two groups had different needs, and as a whole, were at different levels in their Chemistry knowledge. Group A was found to be stronger than Group B, based on prior results and the results of the diagnostic test. Based on the results of the pre-test, a tailored Intervention Programme was designed for each group. This was an important premise behind the Intervention Programme. We specifically wanted to address and meet the students' needs, rather than approach them with our own preconceived notions of what they found difficult, or what was lacking in their understanding (Berg, 2005). This programme was designed to run over a course of nine weeks within the thirteen week semester. It consisted of tutorials covering the basic chemical concepts, gaps in prior knowledge that were shown to be an issue by the diagnostic pre-tests and to address specifically their chemical misconceptions. A variety of teaching and learning techniques were used within the tutorials, including active learning, problem-based learning, group work and a constructivist approach when appropriate (Coll and Taylor, 2001). Some problems noted in Phase 1 were inconsistent attendance at the weekly tutorials. Not all the students to whom the programme was offered decided to participate and those that did participate did not attend every week. This also meant that not all of the 'at risk' students attended, and the inconsistent attendance affected the number of students whose progress could be validly monitored.

b) Phase 2-Expanded Intervention Programme

Due to the positive results of Phase 1 Intervention Programme (see Results Section a), it was decided to run it again, but this time to expand the scope of the programme. Taking into account some of the limitations of Phase 1, we devised an Expanded Intervention Programme (Phase 2). This involves a programme running over two semesters and starting in the students' first year. Our findings in Phase 1 led us to believe that the students' prior chemical knowledge was quite poor, and we believed that the earlier the students were targeted the better. Part 1 began in first year in the second academic semester of 2009-2010, following a 'General Chemistry' module, and continued as Part 2 in second year in the first academic semester of 2010-2011 (as in Phase 1). Part 1 consisted of 10 weeks of tutorials, which concentrated on basic Chemistry ideas and concepts and Part 2, which consisted of 9 weeks of tutorials, focused on chemical calculations, and in particular, the mole concept. The programme was developed for the same two groups of students (Group A and Group B) as well as a third course group (Group C), all of whom had been previously identified as low achievers. Even though all the students showed similar misconceptions based on the results of the diagnostic testing, the tutorials were designed to cater to each group's needs and moved at different paces. Both parts of Phase 2 were advertised in the same manner as Phase 1 at the start of each semester. For Part 1, the same pre- and post-tests of chemical concepts and misconceptions were administered in the first and the last tutorial sessions with the students as in Phase 1. For Part 2 a different diagnostic test was used, which focused on chemical calculations using the mole concept. Similarily, the results of the pre-test were used to design the science content of the programme for each group. Table 3 shows the numbers of students involved in Phases 1 and 2 of the Intervention Programme.

	No. of students tutorials were offered to	No. of students who completed pre test	No. of students who completed post test	No. of students who completed both pre and post test
Phase 1				
Group A	25	18	14	12
Group B	24	16	16	13
Total	49	34	30	25
Phase 2 (Part 1)				
Group A	39	15	10	5
Group B	35	22	16	7
Group C	28	16	13	8
Total	102	53	39	20
Phase 2 (Part 2)				
Group A	39	10	6	3
Group B	35	12	5	4
Group C	28	15	6	2
Total	102	37	17	9

Table 3: Information on number of students participating in both Phase 1 and Phase 2

Both parts involved a blended learning approach, which included a combination of face-to-face teaching and learning, as well as online resources and elements of formative assessment. The main limitation of Phase 2 was poor and inconsistent attendance at the tutorials and the self-selected nature of the sample, which had an effect on the results.

Both phases of the intervention programme were optional for the students; attendance was voluntary, and they did not receive any extra course credits for taking the programme. We feel that this was a limitation of the programme, in that the experimental groups were self-selected. Perhaps some students who would have benefited from the programme did not choose to attend, and those who did attend were not necessarily those in greatest need.

c) Analysis of the diagnostic tests

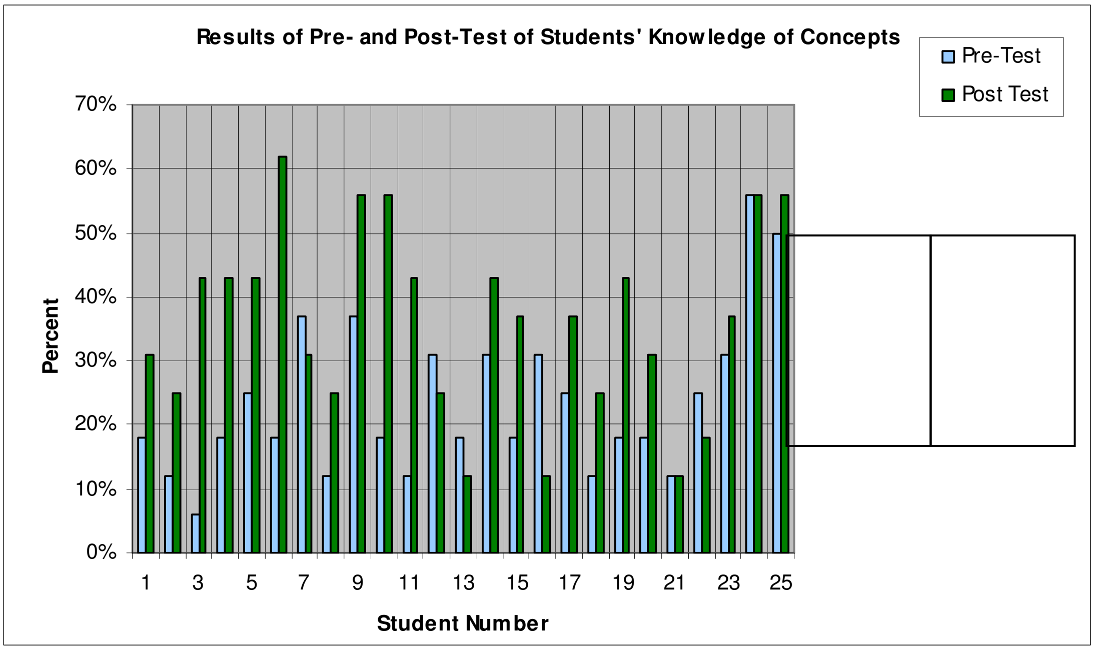
The tests from both Phase 1 and Phase 2 Intervention Programmes were graded using a 2 point marking scheme. Students were given 0 for an incorrect answer and 1 for a correct response for both multiple choice and free response questions. It was decided not to weight any of the questions. Once the tests had been graded, the responses to each question were coded and analysed using the software package SPSS 15.0 and 16.0. All data obtained were subjected to mean, standard deviation and significance testing. In order to determine whether significant differences were present, both paired and independent t-tests were run. When testing for differences between the pre- and post-test paired samples t-tests were run. When examining how the Intervention Programme had effected both current and later performance in Chemistry (where possible), independent t-tests were carried out using the students' attendance record at the Intervention Programme and their marks in their Chemistry module examinations. In order to have been included in this test a student had to have attended at least 6 of the 9 tutorials sessions. This lowered the numbers from 21 to 12 for Group A and from 25 to 13 for Group B, in Phase 1. The Expanded Intervention Programme experienced even lower numbers due to poor attendance, with Group A having only 5 students who met the criteria, Group B had 7, and Group C had 8. The students' results in both the pre- and the post–tests were examined against the students' previous background in Chemistry at Leaving Certificate level. Due to the non–parametric nature of the data, Wilcoxon's test was used to test for significance.

Results and analysis

Phase 1 Intervention Programme

i) <u>Pre- and post- test results</u>

Overall, positive results were experienced in Phase 1 of the study. Fig. 3 shows the results of students in both groups in the pre- and post-test.



Students in Group A experienced significantly higher results in the post-test. (M = 39.0, SE = 4.62, p = 0.014) when compared to the pre–test (M = 29.7, SE = 4.17).

The students in Group B also experienced significantly higher results in the post-test (M = 41.3, SE = 4.49, p = 0.003), when compared to the pre–test (M = 22.0, SE = 2.86).

ii) <u>Comparison with grades on chemistry modules</u>

The effect of the Intervention Programme on results in both the concurrent 'Inorganic Chemistry' module and a subsequent 'Environmental Chemistry' module were positive. This is indicated in Fig. 4.

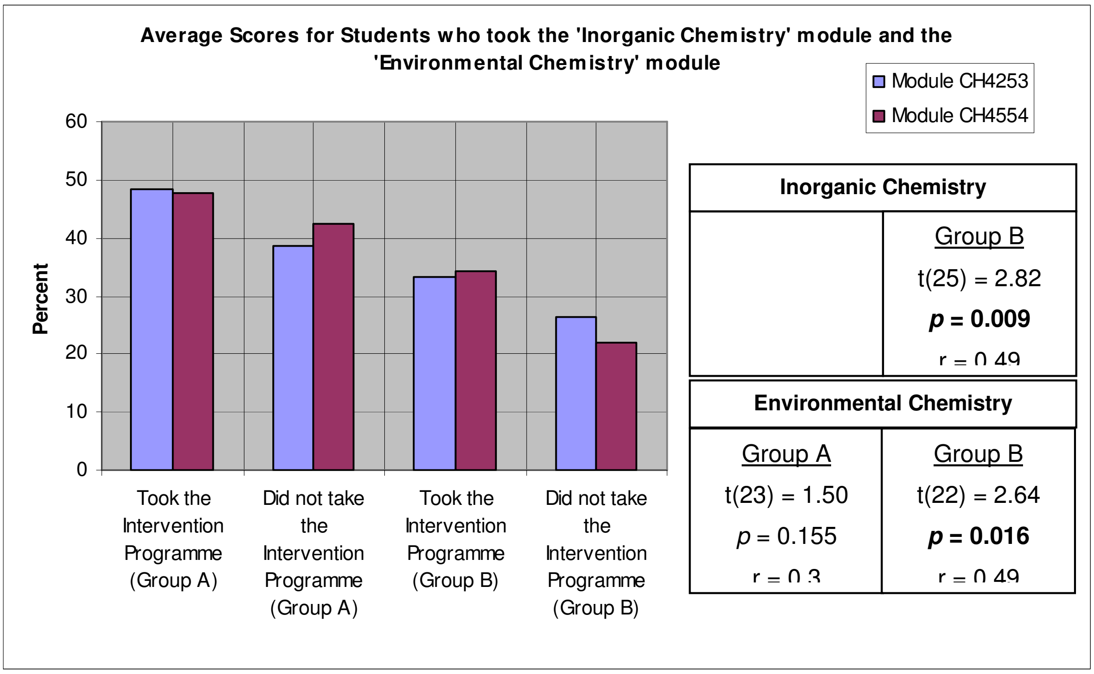


Fig. 4: Comparison of results in concurrent and subsequent Chemistry modules.

In the 'Inorganic Chemistry' module (concurrent), students in both groups that took part in the Intervention Programme did better than their peers who did not. In Group A participants in the Intervention Programme experienced higher grades (M= 47.6, SE = 3.38, p = 0.138) than those who did not take part in the Intervention Programme (M = 40.2, SE = 3.22). Participants of the Intervention Programme in Group B experienced significantly higher grades (M = 34.0, SE = 2.51, p = 0.009) than those in the group who did not take part in the Intervention Programme (M = 21.8, SE = 3.47).

There was thus a greater 'value-added' effect for the weaker group of students (Group B), as one might expect. It was decided also to evaluate the performance of the two groups in a subsequent 'Environmental Chemistry' module, taken in the second semester of second year. Students who took part in the Intervention Programme were also found to have better grades than those who did not. Students in Group A who participated in the Intervention Programme had higher grades (M = 47.6, SE = 2.29. p = 0.155) than those who did not (M = 38.3, SE = 5.79). Those in Group B who took part in the Intervention Programme had significantly higher grades (M= 33.3, SE = 2.17, p = 0.016) than those who did not (M= 26.4, SE = 1.40). Overall, there was a lower class failure rate in the 'Inorganic Chemistry' module in the year 2008 (33.3%) (after the Intervention Programme), than in 2007 (41.6%). 82% of the fail grades in this module in 2008 were awarded to students in Group A and Group B, compared to 95% in 2007. Most of the failures were in the non-attending students in both modules.

iii) Student background

The students' background in chemistry was also examined in Phase 1. 30% of the students in Group A who completed both the pre- and post-test had Leaving Certificate Chemistry, compared to 15% of Group B. Having taken Chemistry for the Leaving Certificate was significant for both groups ($p < 0.05$) in their scores in both the pre- and post-tests. Those with a background in Leaving Certificate Chemistry scored higher than those who had not taken the subject. However, both sets of students, with and without prior Chemistry, showed similar and high levels of misconceptions.

b) Phase 2-Expanded Intervention Programme (Part 1)

i) Pre- and post-test results

Positive results were experienced in Part 1. Fig. 5 shows the results of students in both groups in the pre- and post-test.

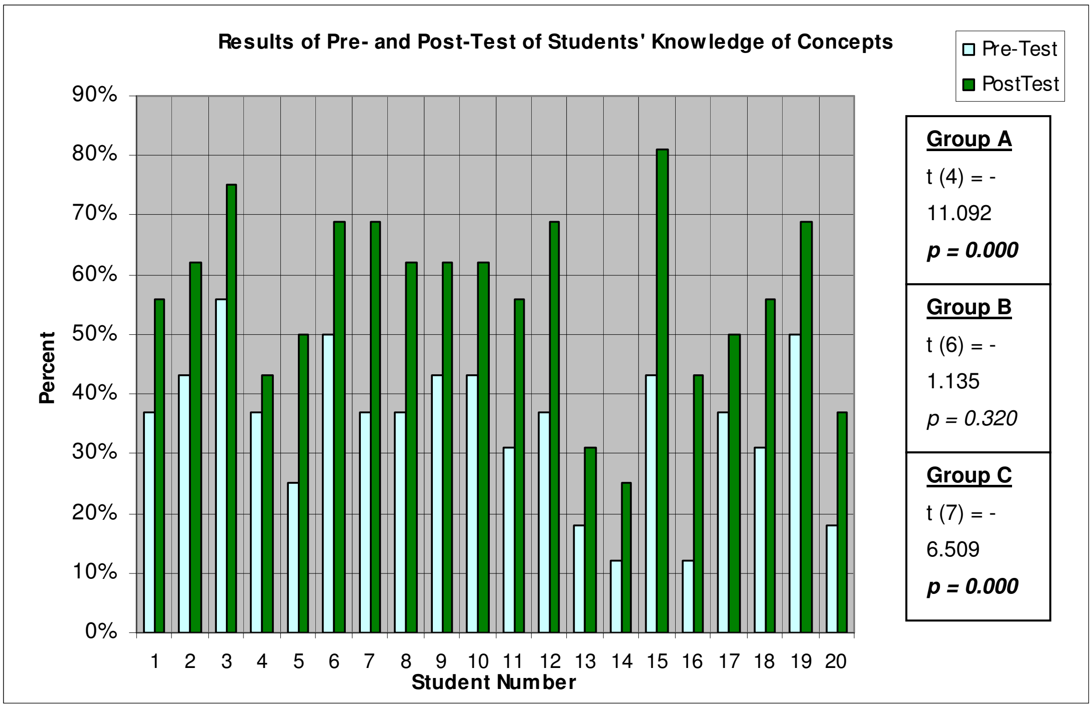


Fig. 5: Comparison of pre- and post -tests for Group A, Group B and Group C.

Participants in Group A experienced significantly higher results in the post-test after taking part in the Expanded Intervention Programme (M=64.1, SE=1.89, p = *0.000*) than in the pre-test (M=39.7, SE=2.32). Group A had the highest attendance rate during Part 1, attending 72% of the tutorials.

Participants in Group B experienced higher results in the post-test after taking part in the programme (M=48.2, SE=11.9, p = *0.320*) than in the pre-diagnostic test (M=39.6, SE=5.04). Group B showed the lowest attendance rate for Part 1, attending 59% of the tutorials. Participants in Group C also experienced significantly higher results in the post-test after taking part in the programme (M=49.0, SE=6.75, p = *0.000*) than in the pre-test (M=27.6, SE=5.19). Group C attended 68% of Part 1 tutorials.

ii) <u>Comparison with grades in the concurrent chemistry module</u>

Fig. 6 shows the results from all three groups in the concurrent 'General Chemistry' module, comparing those who took the Intervention Programme with those students who did not.

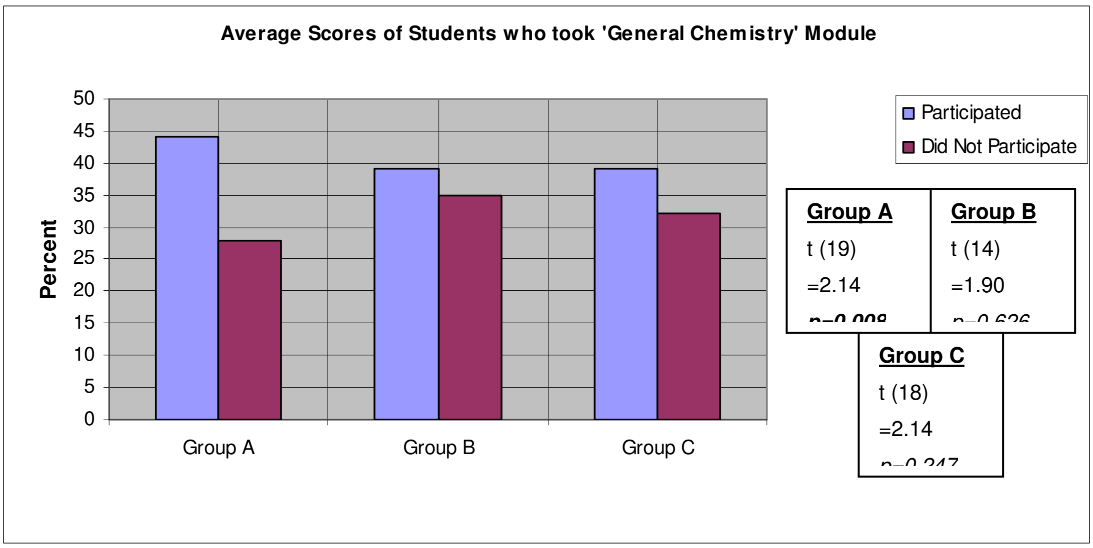


Fig. 6: Comparison of Results in 'General Chemistry' module.

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c) Phase 2-Expanded Intervention Programme (Part 2)

i) Pre- and Post-Test Results

Fig. 7 shows the results of students in both groups in the pre- and post-test in Part 2.

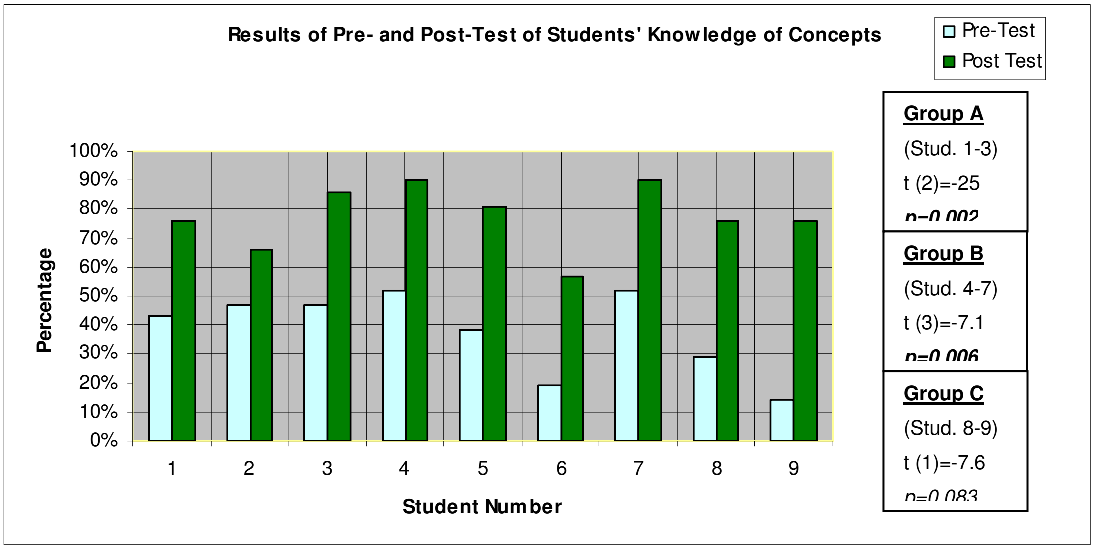

Fig. 7: Comparison of pre- and post-tests for Group A, Group B and Group C.

The validity of these results is affected by the small numbers, but all the students showed improvement, which in some cases was very marked.

ii) Comparison with grades on chemistry modules

Where possible, comparisons have been made with students' performance in their concurrent and subsequent Chemistry modules. However for part 2 these data are not yet available.

Part 1: 60% of the students in Group A who completed both the pre- and post-test had Leaving Certificate Chemistry, compared to 14% in Group B. The students in Group C were slightly higher with 25% having done Leaving Certificate Chemistry. Having Leaving Certificate Chemistry was significant for all groups ($p < 0.05$) in their scores in both the pre- and post-tests. Once again, those with a background in Leaving

Certificate Chemistry scored higher than those who had not taken the subject. However similar levels of chemical misconceptions were found for all students, with or without prior Chemistry.

Part 2: 66% of the students in Group A who completed both the pre- and post-test had Leaving Certificate Chemistry, 50% in Group B and 50% in Group C. Chemistry was significant for all groups ($p < 0.05$) in their scores in both the pre- and post-tests, those with a background in Leaving Certificate Chemistry scored higher than those who had not taken the subject.

iv) Interaction of students with web-based resources

During Part 1 and Part 2, a variety of web-based materials were made available to the participating students in addition to printed materials. A total of 669 visits were made to the web site during Part 1 and 678 visits during Part 2. The website contained tests and quizzes, resources used in the tutorials and links to helpful websites. It is important to note that all students who attended any one of the tutorials were registered on the site and had access to it. The most popular resources accessed by the students were the PowerPoint presentations that were used each week during the face-to-face tutorials. These presentations included animations of chemistry concepts being taught at the time, and also examples that the students worked through during the tutorials.

Discussion and conclusions:

The overall results of the Intervention Programme were positive, with all students who took part in the programme experiencing gains, in both the pre- and post-tests, and also in their performance in both concurrent and subsequent chemistry modules that have been examined to date. Results show that students who have studied chemistry before entering third level perform significantly better. This highlights the need to address the problems of those who have not done chemistry before and are thus unprepared to study chemistry in higher education. However, even those who had done Chemistry before, performed poorly on many of the test questions, showing a weak understanding of basic chemical ideas, and had many chemical misconceptions. In both Phase 1 and Phase 2 of the Intervention Programme, the tutorials and web based resources have been successful to some extent in targeting students' specific difficulties and misconceptions in certain areas.

However, the main limitation of this programme was the voluntary nature of participation. Only a proportion of the students 'at risk' participated and even for those who did attend, their attendance was inconsistent, particularly in Phase 2. Results from Phase 2 were affected by the low atendance rates; however, the small sample size was adequate to show significant results. It seems likely that the better and more motivated students took up this opportunity to improve their understanding of chemistry, and this may be reflected in the performance on the concurrent and subsequent examinations, and the improvements noticed may also be due to the self-selected nature of the sample. Other limitations were that Phase 1 was started during the students' second year, which may be too late; this was rectified in Phase 2. Also Phase 1 was run for one semester, whereas in Phase 2 this was extended to two semesters, to allow for greater coverage of basic Chemistry topics.

For future work, student workbooks are being developed to be used in the tutorials and for self-study. A NAIRTL (National Academy for Integration of Research in Teaching and Learning) grant was obtained in 2010 for the development of the workbooks and dissemination of the materials. It is intended to use an interactive classroom response system in the form of clickers, leading to more formative assessment. Interviews will also be conducted with students in order to investigate the students' thinking processes that lie behind the responses to their pre- and post-tests. (Osbourne and Gilbert, 1980; Gernett and Treagust, 1992; Schmidt, 1997)

We intend to test the influence of students' gender, Leaving Certificate points and the level of mathematics taken at Leaving Certificate. It is also planned to compare the students' results in chemistry modules as they progress through their course and their overall performance in their degree. We hope to see persistence of the improvement in the performance of the experimental group, as compared to those who did not participate. Poor and inconsistent attendance is a major factor in student achievement and is linked to student motivation. We intend to look at ways of improving students' motivation. Students' level of confidence in relation to their ability to perform a variety of chemistry-related tasks will be explored and the effect of the Intervention Programme on students' confidence levels will be assessed.

We believe this Intervention Programme has demonstrated the value of using diagnostic testing to ascertain the weaknesses in the students' background knowledge and understanding that prevents them from succeeding in further study of Chemistry. Tailoring tutorials to the students' actual needs, that is teaching 'smarter', enables us to deal with fundamental problems, for example, persistent chemical misconceptions and lack of prior knowledge, that undermine their attempts to study Chemistry further. We believe there is also a need to address the students' coginitve level, which other work has shown may be inadequate for successful study of Chemistry (Sheehan, 2010), and to address the related mathematics 'problem'. We suggest that this could be done by infusing aspects of cognitive acceleration into the undergraduate chemistry courses and dealing specifically with the transfer of mathematical skills into chemistry. We also believe that the problem of chemistry misconceptions in students must be addressed in the mainstream chemistry programme for them to be dealt with successfully. 'Early and often' might be a useful slogan for intervention programmes designed to improve student retention in science degrees.

Acknowledgements

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Appendix

A minimum of six subjects are studied and examined, and can be studied at higher and ordinary level. Each pupil receives points depending on their grade in each subject. A pupil's six best examination subjects are used to calculate their final points score and this is then used to gain entry into higher education courses. An A1 grade in a higher level paper can earn a pupil 100 points and a D3 grade earns 45 points (see Table A1). A maximum of 600 points can be achieved through taking 6 subjects at higher level.

Leaving Certificate Grade	Higher Level Paper Points	*Ordinary Level Paper Points*
A1	100	*60*
A2	90	*50*
B1	85	*45*
B2	80	*40*
B3	75	*35*
C1	70	*30*
C2	65	*25*
C3	60	*20*
D1	55	*15*
D2	50	*10*
D3	*45*	*5*

Table A1: Points achieved for grades in the Leaving Certificate Examination.

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Appendix H

Graphical Results Phase 2 – Part 1 Pre-Tests

Pre-Diagnostic Test Results Phase 2, Part 1

Question 1

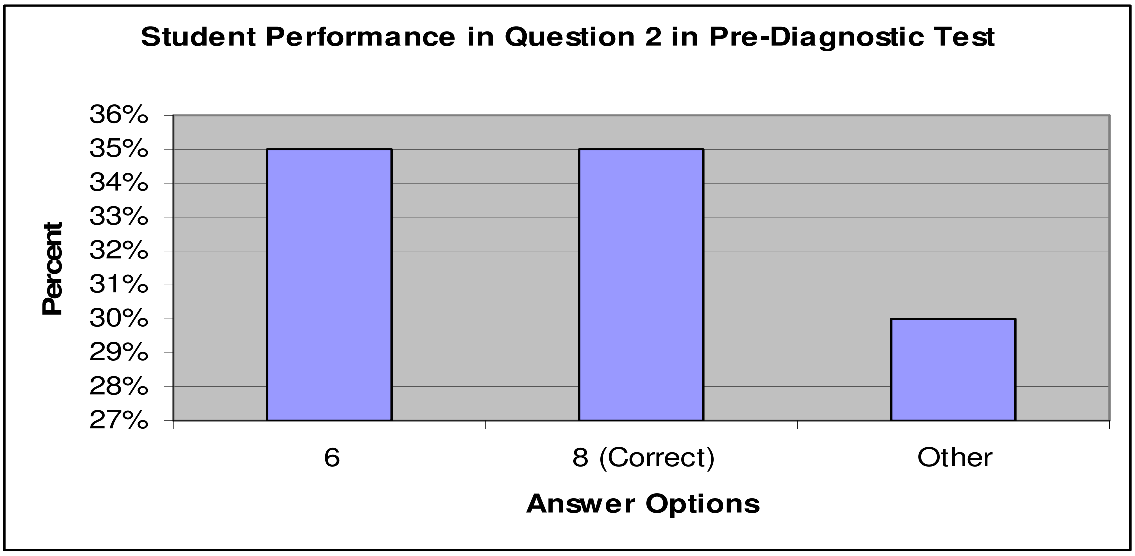
Q1. How many atoms are in the formula $Al_2(SO_4)_3$?
3 __
5 __
17 __

This question asked students to determine how many atoms were present in a particular compound. In order to correctly answer this question, students needed to be familiar with what an atom was and also what the coefficients written beside the symbols meant. 10 (50%) of the students got this question correct, 6 (30%) chose answer 5 and 4 (20%) of the students thought the compound was made up of 4 atoms.

Question 2

Q2. The radioactive isotope ^{14}C has how many neutrons? (z = 6)
6 ___
8 ___

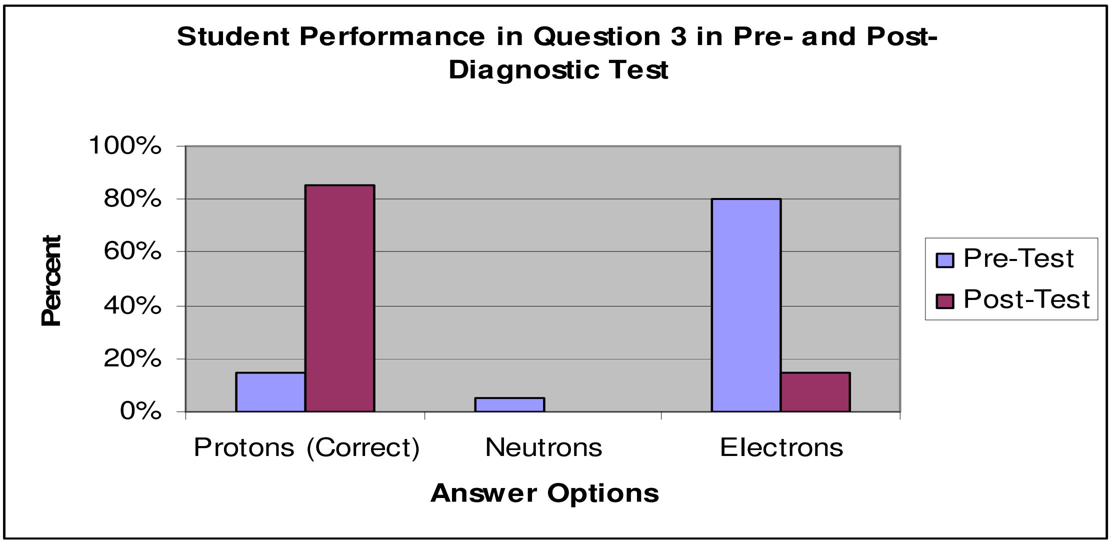
Other ___



This question asked students to calculate how many neutrons were present in an isotope. To be able to answer this question, students needed to know how to calculate the number of neutrons in an atom and also that the symbol ‘Z’ represents the atomic number, the number of protons present in an atom. 7 (35%) of the students selected the correct answer of 8, 7 (35%) selected the answer 5 and 6 (30%) of the students selected answer 6.

Question 3

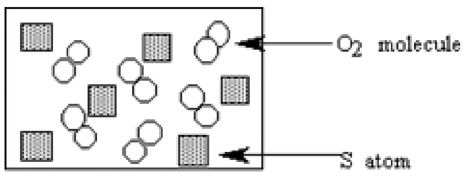
Q3. The identity of an element is determined by the number of which particle?
Protons ___
Neutrons ___
Electrons ___



This question tested students' understanding of how an element's identity is determined. This question was used in both the pre- and post-diagnostic test. In the pre-test, 3 (15%) of the students selected the correct answer, this increased to 17 (85%) selecting the correct answer in the post-test. 1 (5%) student chose neutrons in the pre-test and none of the students chose this option in the post-test. 16 (80%) of the students thought the identity of an element was determined by electrons in the pre-test and 3 (15%) of the students still believed this to be true in the post-test.

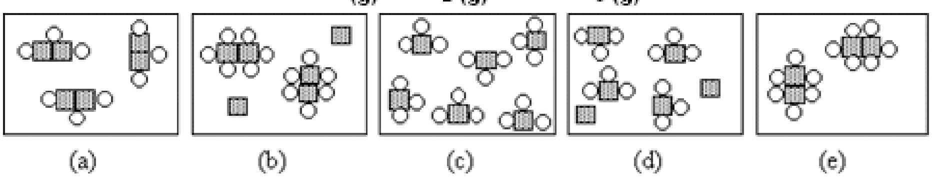
Question 4

Q4. The diagram represents a mixture of S atoms and O_2 molecules in a closed container.

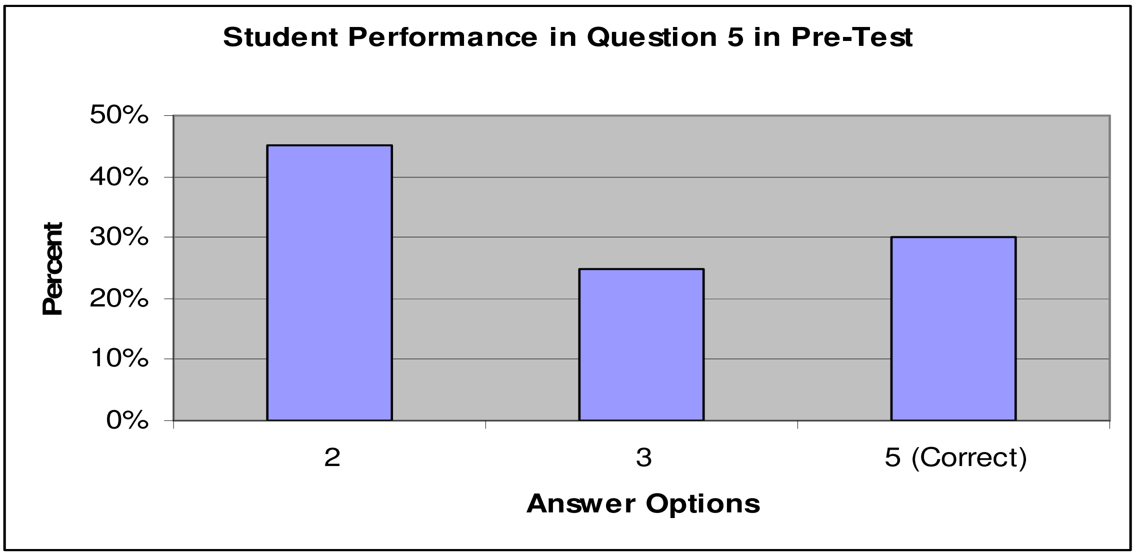


Which diagram shows the results after the mixture reacts as completely as possible according to the equation?

$$2S_{(g)} + O_{2\,(g)} \rightarrow 2SO_{3\,(g)}$$



This question sought to test students' understanding about chemical



equations. It was used in both the pre- and post-test. 1 (5%) of the students chose the correct answer D in the pre-test, this increased to 11 (55%) choosing the correct answer in the post-test. 16 (80%) of the students selected incorrect answers (A, B, C or E) in the pre-test, 7 (35%) of the students got this question incorrect in the post-test choosing answers B, C or E. This suggests that students have difficulty understanding the difference between the coefficient '2' and the subscript '3' in $2SO_3$. 3 (15%) of the students did not answer this question in the pre-test, 2 (10%) of the students did not attempt it in the post-test.

Question 5

Q5. How many moles of ions are there per 1 mole of $Al_2(SO_4)_3$?

2 ___

3 ___

5 ___

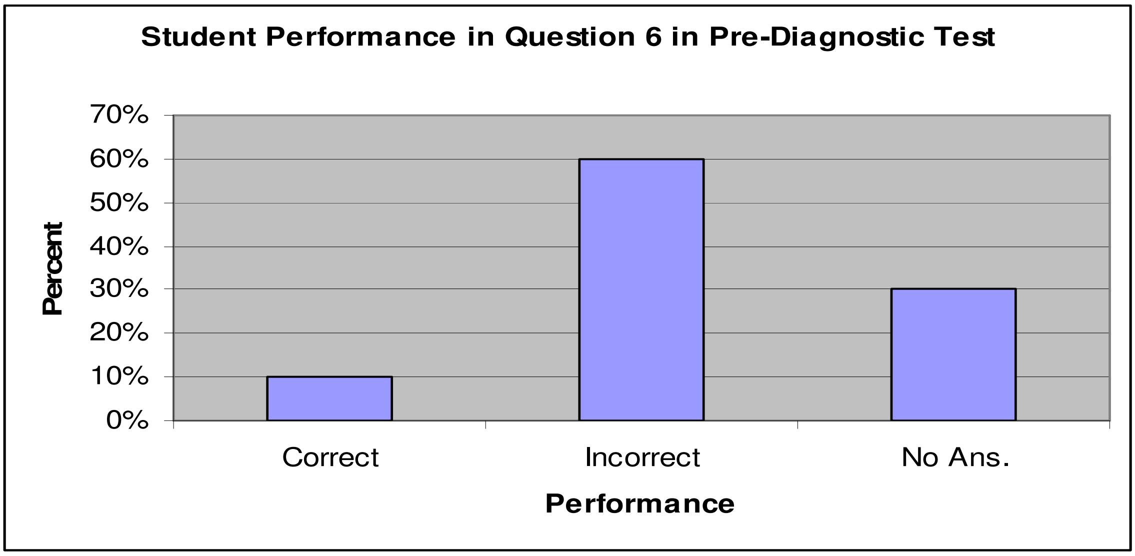
.

This question asked students to calculate the number of moles of ions in a particular compound. To complete this question correctly, students had to be able to break up the compound into ions. (30%) of the students chose the correct answer 5, 5 (25%) selected answer 3 and 9 (45%) of the students thought that there were 2 mole of ions present in the compound.

Question 6

Q6. Write the electronic configuration (s,p) of Chlorine. (z = 17)

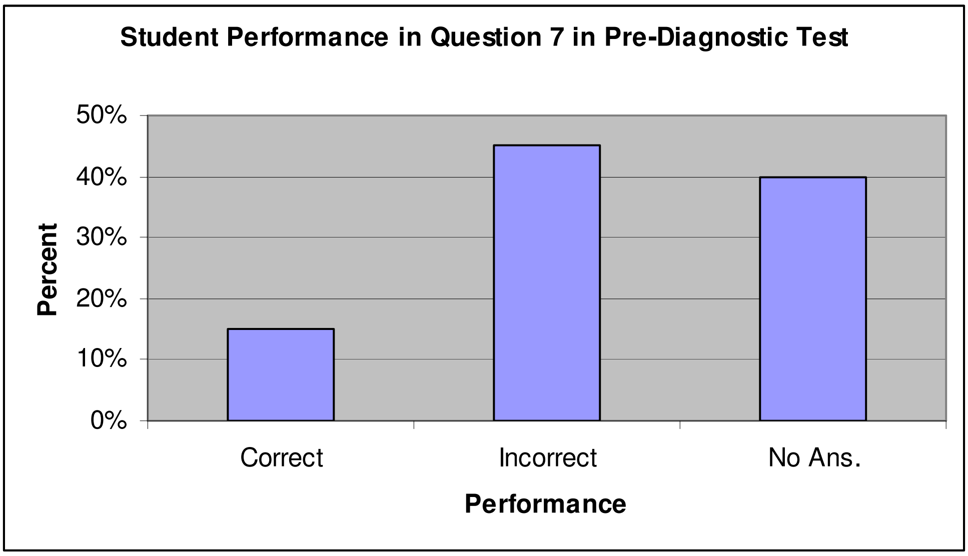
This question tested students' ability to correctly write the electronic



configuration of Chlorine. To answer this question successfully, students needed to have an understanding of the number of electrons in s and p orbitals. 2 (10%) of students got this question correct, 12 (60%) got this question incorrect and 6 (30%) of students did not answer the question.

Question 7

Q7. How many moles of Aluminium atoms are there in 9 x 10^{22} atoms of aluminium? (Relative Molecular mass Al = 13)

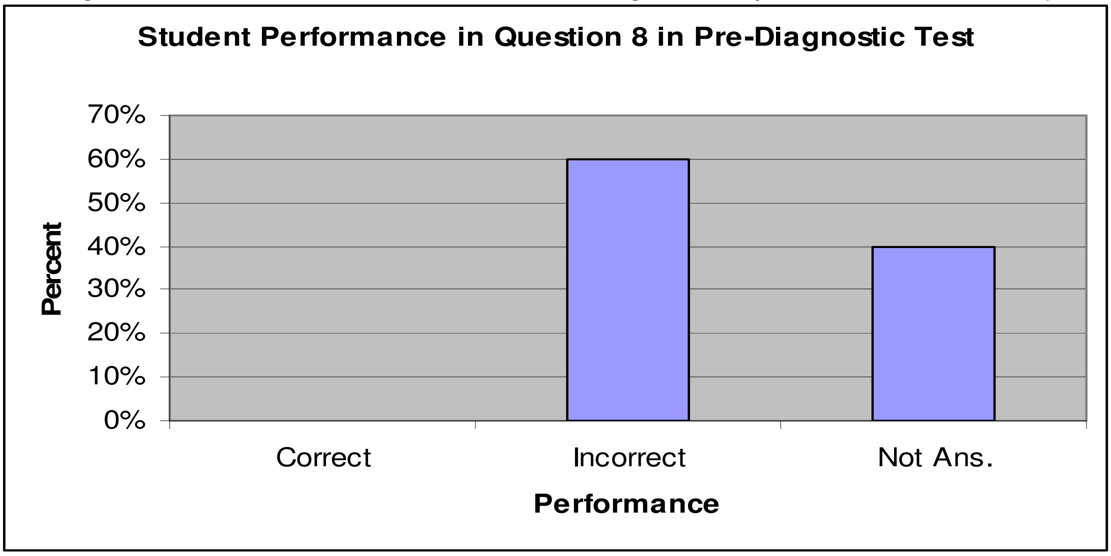


This question examines students' ability to calculate the number of moles of atoms present in 9×10^{22} atoms of Aluminium. For this question students need to be familiar with Avogadros number. 3 (15%) of the students got the question correct, 9 (45%) of the students got it incorrect and 8 (40%) of the students did not answer the question.

<u>Question 8</u>

Q8. Write the formula for Sodium Sulfide

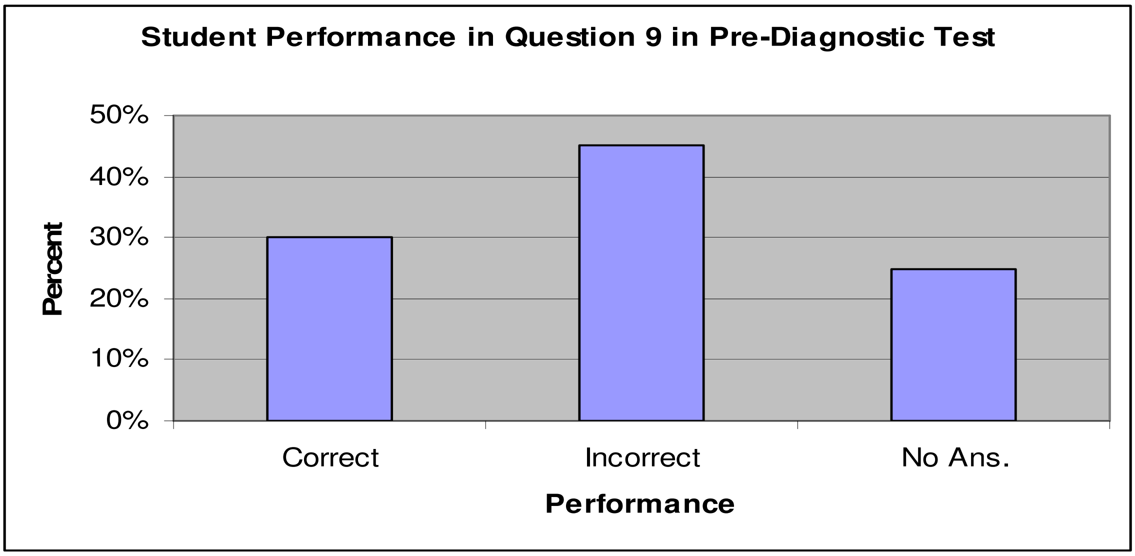
This question asked students to write the chemical formula for a compound. To correctly answer this question, students needed to be familiar with the charges of the ions. None of the students got this question correct, 12 (60%)



got the question incorrect and 8 (40%) of the students chose not to answer the question.

<u>Question 9</u>

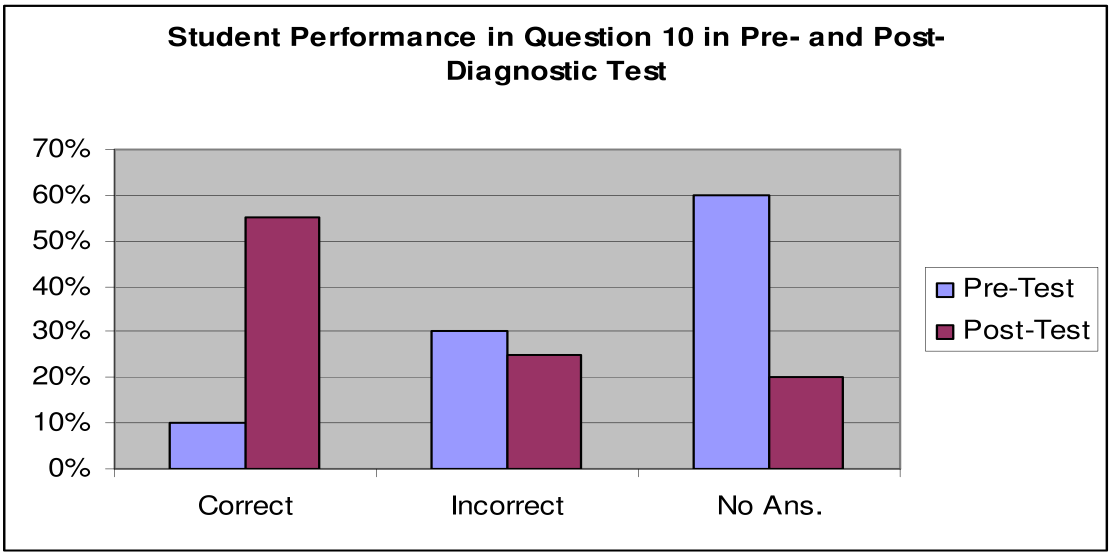
Q9. What is the oxidation number of the N atom in the NO_3^- ion?



In this question, students are asked to work out the oxidation number of Nitrogen in a compound. In order to complete this question successfully students needed to be familiar with the rules for assigning oxidation numbers. 6 (30%) of the students got this question correct, 9 (45%) got this incorrect and 5 (25%) chose not to answer this question.

Question 10

Q10. Use the VSEPR theory to deduce the shape of the ammonia molecule, NH_3



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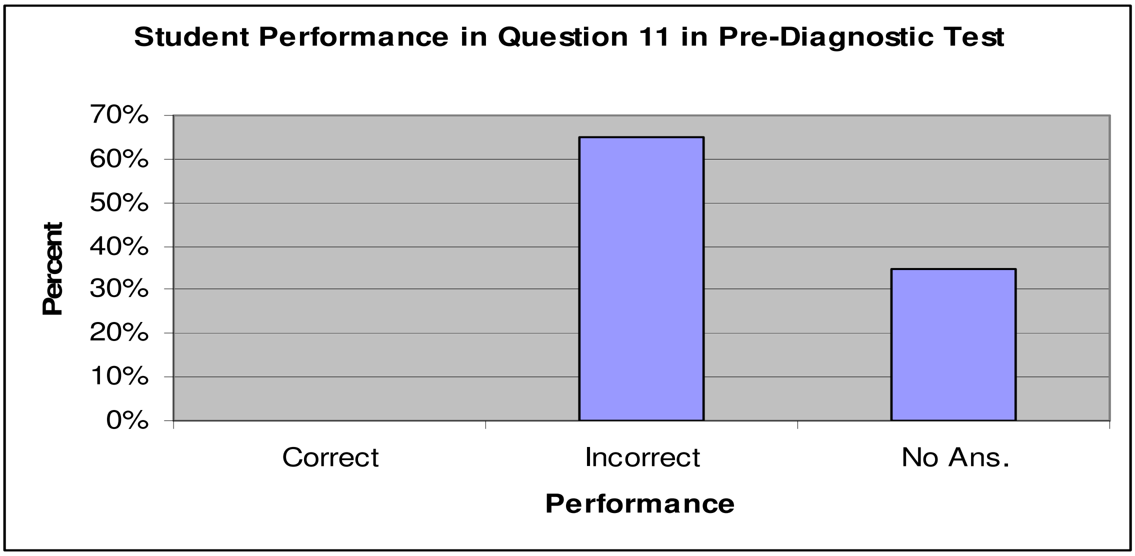
This question asked students to deduce the shape of the ammonia molecule. To answer this question, students needed to be familiar with the type of bonding that the particular molecule had. This question was used on both the pre-test and the post-test. Only 2 (10%) of the students got the question correct in the pre-test, this increased to 11 (55%) in the post-test. 6 (30%) of the students got this question incorrect in the pre-test and 5 (25%) in the post-test. 12 (60%) of the students chose not to answer this question in the pre-test and 4 (20%) still did not answer the question in the post-test.

Question 11

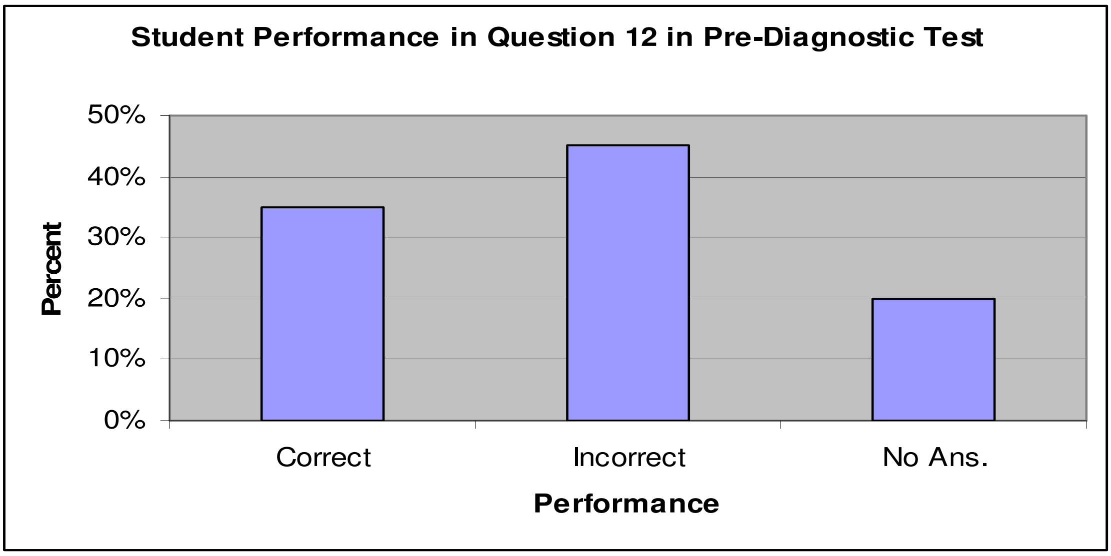
Q11. Write the formula of Sodium Sulphate



This question asked students to write the chemical formula for a particular compound. To successfully answer this question, students needed to be familiar with the charges on the ions and the common group ions. None of the students answered this question correctly in the Pre-test, 13 (65%) answered it incorrectly and 7 (35%) of the students did not answer this question.

Question 12

Q12. Balance the following equation
$K_{(s)} + H_2O \rightarrow KOH_{(aq)} + H_{2\,(g)}$



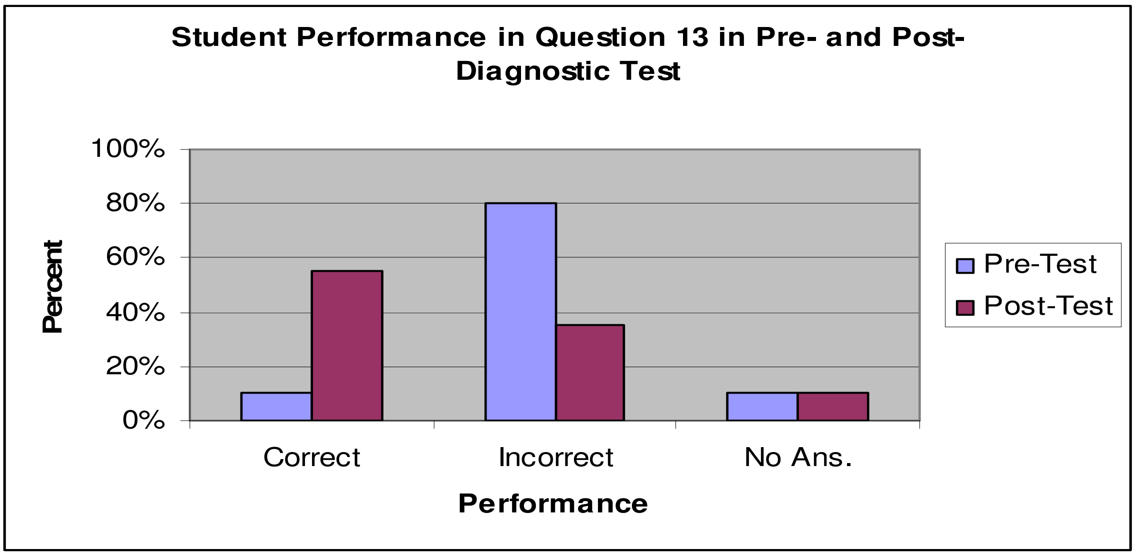
This question asked students to balance an equation. In order to complete this question students needed to be familiar with the difference between coefficients and subscripts used in a chemical equation. 7 (35%) of the students got the question correct, 9 (45%) got it incorrect and 4 (20%) of the students did not answer this question.

Question 13

Q13. Magnesium reacts with oxygen to produce Magnesium oxide according to the equation:

$2Mg_{(g)} + O_{2\,(g)} \rightarrow 2MgO_{(g)}$

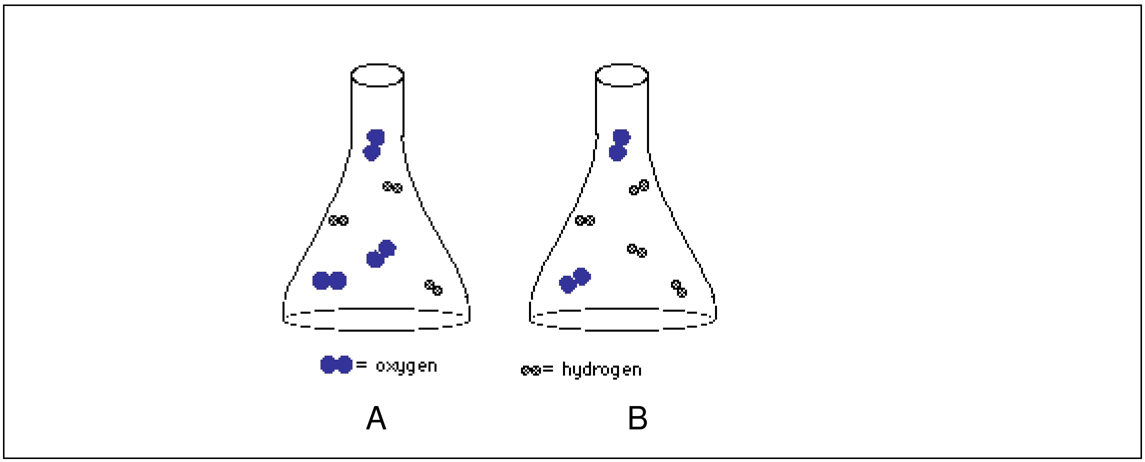
If a student burns 9g of magnesium in excess oxygen (i.e. there is plenty of oxygen present to ensure that all of the magnesium reacts), what mass of Magnesium Oxide will be formed?

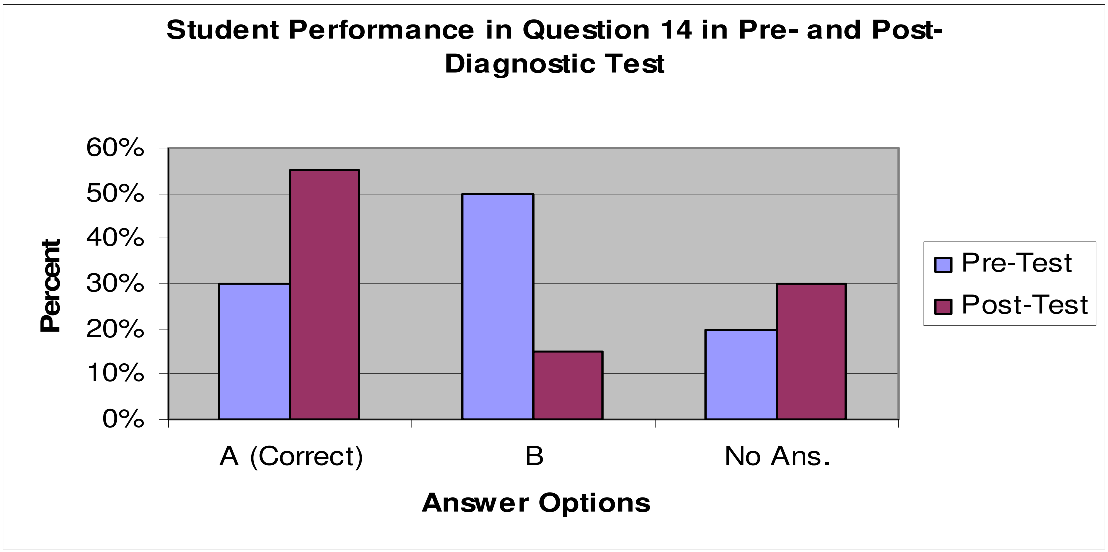


This question tested students' ability to complete chemical calculations using the chemical equation for the reaction. To answer this question successfully students needed to have an understanding of the mole relationship in the equation. In the Pre-Test, only 2 (10%) of the students got this question correct, this increased to 11 (55%) getting the correct answer in the Post-Test. 16 (80%) got this question incorrect in the Pre-Test and 7 (35%) got it incorrect in the Post-Test. 2 (10%) of the students chose not to answer this question in both the pre-Test and the Post-Test.

Question 14

Q14. Which of the flasks below will contain a mixture when all the hydrogen reacts with oxygen to give water? (H_2O)

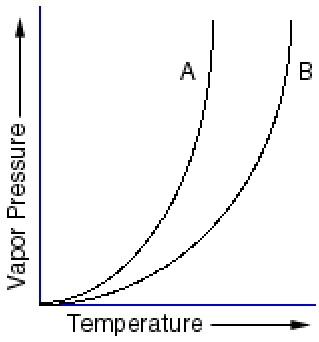


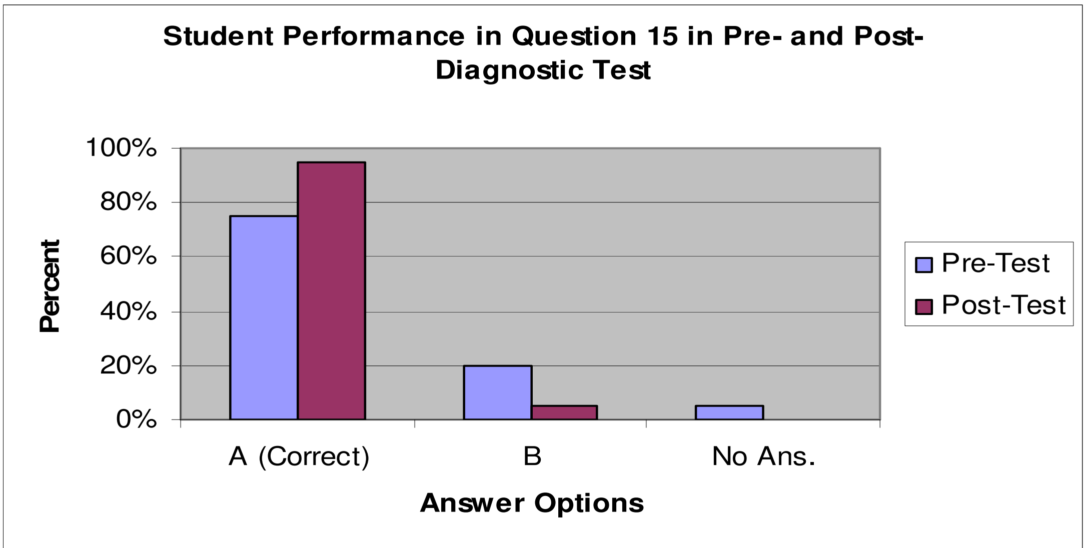


This question asked students to determine which flask would contain a mixture when all the Hydrogen reacts with the Oxygen. In order to complete this question successfully, students needed to have a clear understanding of what a mixture is. This question was used on both the Pre- and Post-Test. In the Pre-Test, 6 (30%) of students chose the correct answer, this increased to 11 (55%) in the post-test. 10 (50%) of the students chose the incorrect answer flask B in the pre-test and 3 (15%) chose this option in the post-test. 4 (20%) did not attempt this question in the pre-test and 6 (30%) did not attempt it in the post-test.

<u>Question 15</u>

Q15. Drops of water and ethanol are placed on an overhead projector and the ethanol drop is seen to evaporate more rapidly. The graph below compares the vapour pressures of ethanol and water. Which curve corresponds to ethanol?

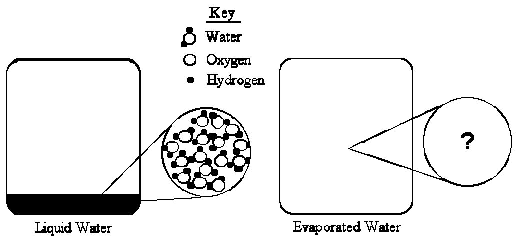




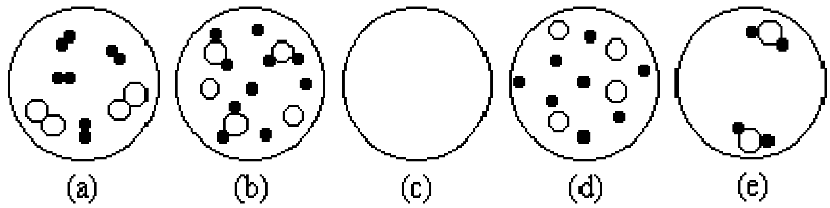
In this question students are asked to determine whether ethanol or water evaporates first. In order to complete this question students need to be able to analyse the graph correctly. 15 (75%) of the students got this question correct in the pre-test, this increased to 19 (95%) in the post-test. 4 (20%) got this question incorrect in the pre-test and 1 (5%) got it incorrect in the post-test. 1 (5%) chose not to answer this question in the pre-test. This question was attempted by all students in the post-test.

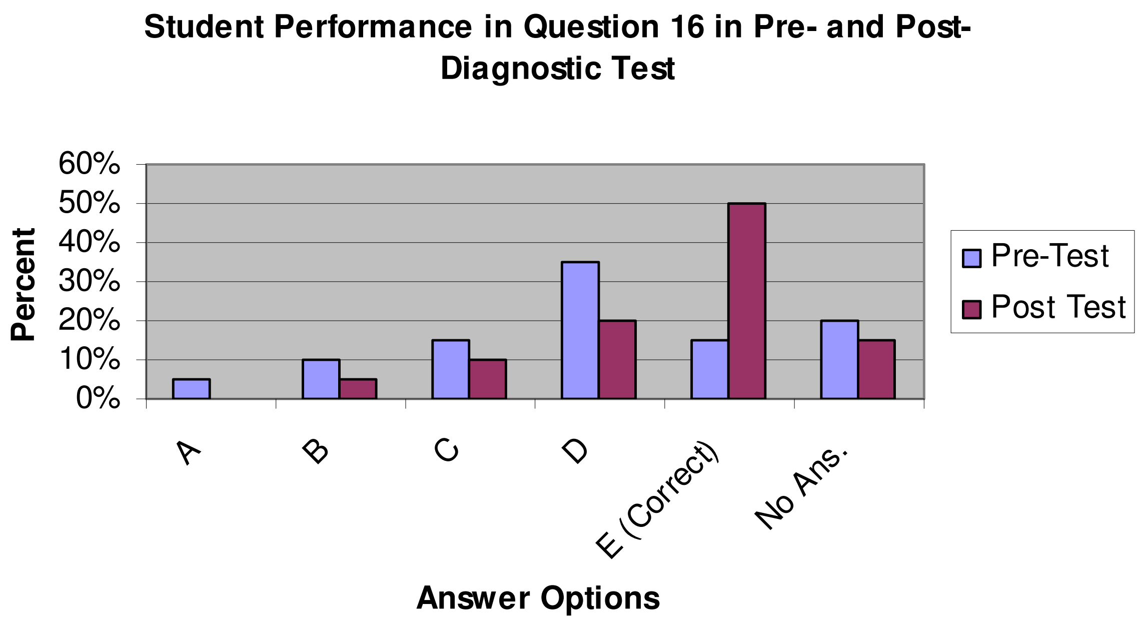
Question 16

Q16. The circle on the left shows a magnified view of a very small portion of liquid water in a closed container.



What would the magnified view show after the water evaporates?





This question tested students understanding of what happens to a water molecule when it evaporates. To answer this question correctly students needed to be familiar with what a molecule was and the states of matter. This question was used on both the pre- and post-diagnostic test. 3 (15%) of the students got this question correct in the pre-test, choosing option E. This increased to 10 (50%) choosing the correct answer in the post-test. 13 (65%) of the students got this question incorrect in the pre-test choosing options A, B, C or D. 5 (35%) got it incorrect in the post-test choosing options B, C or D. 4 (20%) of the students did not answer this question in the pre-test and 3 (15%) of the students did not answer it in the pre-test. The most common answer on the pre-test for this question was option D. This shows that students believe that Hydrogen and oxygen split into individual atoms when they evaporate.