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Learner Experiences of Online Pre-lecture Resources for an Introductory Chemistry Course at an Irish Higher Education Institution

Claire M. McDonnell
Technological University Dublin, claire.mcdonnell@tudublin.ie

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Learner Experiences of Online Pre-lecture Resources for an Introductory Chemistry Course at an Irish Higher Education Institution

A thesis submitted to Dublin Institute of Technology in part fulfilment of the requirements for the award of Masters (M.A.) in Higher Education

by

Claire Mc Donnell

August 2011

Supervisor: Dr Roisin Donnelly

Learning Teaching and Technology Centre, Dublin Institute of Technology

Declaration

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

This thesis was prepared according to the regulations of the Dublin Institute of Technology and has not been submitted in whole or in part for another award in any Institute.

The work reported on in this thesis conforms to the principles and requirements of the Institute's guidelines for ethics in research.

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Claire Mc Donnell,

August 2011

Abstract

The principal aim of this case study was to investigate students' experiences of using online pre-lecture resources and their perceptions of their learning environment for the Introductory Chemistry module concerned. A subsidiary aim was to probe the experience of the lecturer involved of designing and piloting these resources and his perception of their impact on students' learning.

The student cohort who participated were a group of 49 first year level 8 undergraduate chemistry students at Dublin Institute of Technology. These students took an Introductory Chemistry module over their first semester, the aim of which was to bring the level of understanding and knowledge of the entire cohort to a similar standard in the topics covered. One of the module lecturers developed a series of online pre-lecture resources designed to reduce the cognitive load experienced by these learners during their lectures. The basis of this research was the investigation of the qualitative variation in the ways that learners experienced their use of these online pre-lecture resources and their learning environment.

The methodology selected was phenomenography and a mixed methods approach was used which involved an initial quantitative phase (Likert scale survey) which informed the major qualitative phase (phenomenographic interviews) that followed. The survey was distributed twice to the entire student cohort; in the second week of the module and in the first week of the second semester when the module summative examination was complete. The individual phenomenographic interviews were performed with nine participants within the first month of the second semester. A semi-structured interview with the lecturer who had designed the pre-lecture resources was also carried out to allow a comparison to be made between his perceptions of the learning environment and those of the students.

Following analysis of the interviews, categories of description were arrived at for the different experiences students described, four for using the pre-lecture resources and three for perceptions of the learning environment. They were analysed using referential and structural aspects to produce outcome spaces for both units of analysis (the pre-lecture resources and the learning environment). The categories of description for each could be related to surface, strategic and deep approaches to learning and the findings

will inform further redesign of the resources, particularly in relation to the multiple choice quiz component. The lecturer interview provided reinforcement for many of the accounts of experiences that emerged from the student interviews with the exception of a difference in perceptions in relation to the importance of allocating a continuous assessment mark to the resources.

The findings from this study will now be applied to ensure that the intended learning outcomes for this module will be met by students who experience the learning environment in a variety of ways.

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CHAPTER 1

Introduction

'We would never dream of going into the research lab without knowing the latest methodologies and without knowing what those other "experts" out there are thinking about. But we routinely do just that when we go into the classroom.'

(Michael, 2001: 156)

Context of This Research

This work is a case study in which the subject was a cohort of 49 first year level 8 undergraduate chemistry students at Dublin Institute of Technology. The phenomenon of interest was online pre-lecture resources. The learners' experience of using them and their perceptions of their learning environment was examined.

Science and Chemistry Education at Third Level

The complexity of science education is acknowledged by several scientific researchers at the forefront of their fields who have moved from discipline-based to educational research. Carl Wieman, a physicist who received the Nobel prize in 2001 (Wieman, 2006, 2007), Sven Olaf Holgren (Patterson and Rau, 2010), former head of the Physics Department in Stockholm University, and Peter Atkins, former Professor of Chemistry at the University of Oxford (Atkins, 2007; Cardellini, 2008) all recognise that engaging students in active learning is important as is a linking of scientific concepts to applications the learners will be familiar with. The challenge of interacting with a group of students among whom there is usually a wide variation in levels of prior knowledge is also acknowledged (Wieman, 2006).

A theme that resonates strongly in the science education literature is that of using a scientific approach to science education. This has been addressed in physics (Wieman, 2007), chemistry (Reid, 2008; Childs 2009) and biology (Michael, 2001) and these authors argue that teaching staff should be encouraged to approach their teaching in the same way that they carry out their discipline-based research and thus recognise that experimentation and evaluation of alternative methods is required. Other important parallels identified are the gathering and evaluation of objective data, use of modern technology and dissemination of results (Wieman, 2007).

Chemistry Education at Third Level

Chemistry is accepted as being a conceptually difficult subject for a novice learner as well as one that requires that students build on prior knowledge they have acquired in order to progress (Childs & Sheehan, 2009; Seery, 2009a; Reid, 2008). Learners need to be able work on three levels; the macro (what can be seen), submicro or particle (too small a scale to be seen, atoms and molecules represented by models and drawings) and symbolic (chemical formulae). The three levels are sometimes referred to as the representational triplet (Gilbert & Treagust, 2009; Tasker & Dalton, 2006, Johnstone 1993) and are often displayed as a triangle (Johnstone 1993) as shown below in Figure 1.

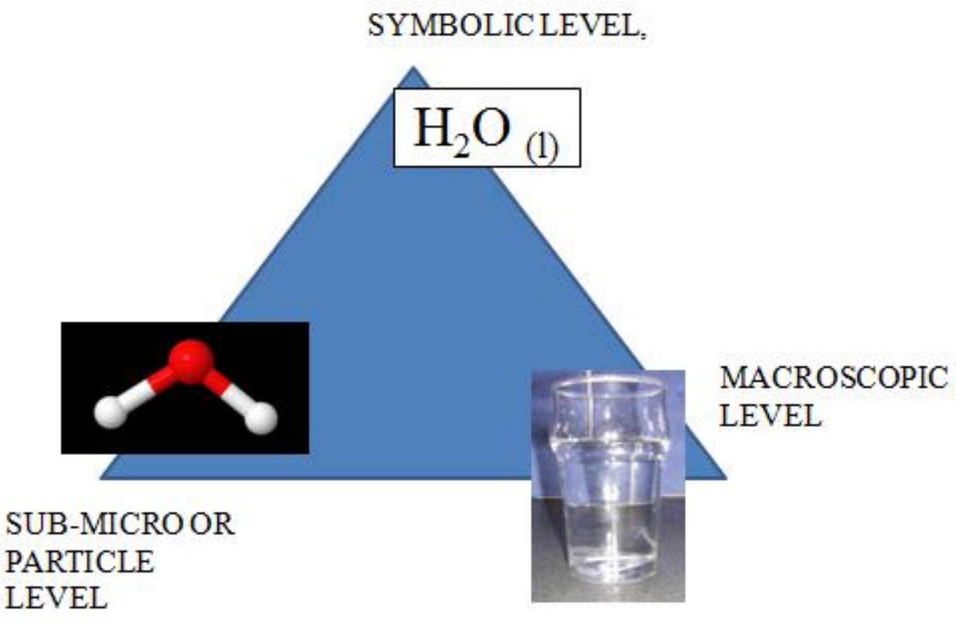

Figure 1: The three levels of representation used in chemistry (based on Johnstone, 1993)

The nature of the material taught and the pedagogical approaches used on introductory chemistry courses at second and third level have been scrutinised recently and several well-respected authors have recommended a thorough review (Johnstone, 2010; Childs, 2009; Reid, 2008). A recurring theme is that greater consideration should be given to cognitive load and thus to ensuring that learners are given the opportunity to embed knowledge in their long term memory by means of processing new concepts in their working memory. The underlying principles of this model of information processing will be discussed in more detail in Chapter 2.

Chemistry Education at Third Level – The Irish Context

Two significant trends occurring in Ireland over the past two decades have been the decrease in the percentage of students taking chemistry as a Leaving Certificate subject (21% in 1987, 14% in 2005, 12.5% in 2010) and the increase in the level of participation at third level; 35% of second level students progressed to third level in 1990, 65% did so in 2005 (Department of Education and Skills, 2011). This has resulted in a change in the type of learners entering third level. The new cohort of students are distinct from the traditional intake in that they are generally not very well-prepared for higher education and may often not know many friends or family members who have experienced third level education. This means that they do not know what to expect or what will be expected of them. Also, it is quite likely that they will not have studied chemistry or higher level mathematics (Childs, 2009; Seery, 2009b; Oireachtas Library & Research Service, 2009). These factors combined mean that they often perceive chemistry to be a difficult subject and may expect to fail or to do poorly in it from the outset.

Many authors have addressed the issue of widening participation in higher education and the consequent changes in types of student entering our colleges and universities (Wieman, 2006; David, 2009; Conway, 2009; O'Connor, 2006; Cottrell 2001). It is emphasised that these different types of learners must be taught using alternative methods to those employed in the past and that higher education institutions need to accept that '*it is not simply enough to open the doors: what goes on behind the doors* *has to change to accommodate new types of student intake'* Cottrell (2001:12). However, one of the positive outcomes of this situation is that good teaching skills are now valued and there is an impetus to examine and to implement some different teaching and learning strategies to support these students.

Chemistry Education at Dublin Institute of Technology

As a result of the widening participation at third level, staff at the School of Chemical and Pharmaceutical Sciences in Dublin Institute of Technology have introduced a variety of measures to scaffold learning for first year chemistry students over the past ten years and the modification of tutorials to become student-centred problem-solving sessions has proven particularly successful in this regard (Mc Donnell & O'Connor, 2005, 2007). The problems that learners encounter can often be attributed to cognitive overload that results when the amount of new information is too great to allow it to be processed meaningfully (Reid, 2008; Johnstone, 1997).

The provision of pre-lecture learning resources is recommended as a strategy that can be adopted to address this issue (Sirhan and Reid, 2001; Sirhan, Gray, Johnstone, & Reid, 1999). Dr. Michael Seery, a lecturer in the School of Chemical and Pharmaceutical Sciences, developed and implemented a suite of nine online pre-lecture resources for one cohort of first year students in Semester 1 of the academic year 2010-11. These resources were designed to introduce core terminology and ideas before each lecture. In addition, feedback was provided online and during lecture sessions and students' understanding was further probed with in-class questions (Seery & Donnelly, 2011).

My research complemented Dr. Seery's work by undertaking a predominantly qualitative analysis of the participants' perception of the effects of implementing these pre-lecture resources on their learning.

Profile of the Student Cohort in This Study

The learners who participated in this research were 49 first year undergraduates (28 male and 21 female) who were enrolled on a chemistry- or physics-based honours (level 8) science degree at Dublin Institute of Technology (DIT), Kevin St. in September 2010. 25 of these students had studied chemistry at Leaving Certificate level and their incoming CAO points level ranged from 315 to 435. The students undertook a 5 European Credit Transfer System (ECTS) credit Introductory Chemistry module over their first semester at DIT for which Dr. Michael Seery was one of their lecturers. The aim of this module is to bring the level of understanding and knowledge of the entire cohort to a similar standard in the topics dealt with so that they can engage in more specialised topics in the following year.

Rationale

Chemistry lecturers of first year students are required to introduce students to a wide range of chemistry principles so that they are ready for a diverse range of more specialised modules when they progress to Year 2. In the Irish education system, student cohorts at third level will include a range from learners who have achieved very good performances in their Leaving Certificate chemistry exam through to those who have not done any chemistry previously at all. A study of first year chemistry undergraduates undertaken recently at Dublin Institute of Technology (Seery, 2009a, 2009b) found that there was a significant difference, consistent over a five-year period, between the average end of year exam marks for the group of students who had completed chemistry at Leaving Certificate level and those who had not. The students who had taken Leaving Certificate chemistry achieved a mark that was on average 14% higher in their end of year exam and this research showed that prior knowledge was the sole predictor for the end of year exam mark. This finding is expected, as a large proportion of literature in this area reports similar results (Dochy, De Ridjtt, & Dyck, 2002; Dochy, Segers, & Buehl, 1999), including some in the context of chemistry (Boujaoude & Giuliano, 1991; Craney & Armstrong, 1985; Sirhan, Gray, Johnstone, &

Reid, 1999). This work has led to the decision by my colleague to implement the use of web-based pre-lecture resources which are intended to support learners who lack prior knowledge in chemistry by introducing them to core terminology and ideas before a lecture.

The current work will investigate the attitudes and perceptions of their learning environment of first year chemistry students on implementation of these online pre-lecture resources. The lecturer who designed and is using the resources is himself undertaking quantitative analysis which will focus on the learners' performance in their module assessments and the extent to which they access the pre-lecture resources. Thus, the qualitative study described in this work will build on previous research by my colleague (Seery, 2009a, 2009b) and complement his ongoing work on supporting learners who lack prior knowledge in chemistry.

Research Aim and Research Question

The aim of this research was, using a collaborative approach, to probe students' perceptions and experiences of the web-based pre-lecture resources implemented in relation to their learning and their attitudes towards chemistry. In addition, the experience of the lecturer concerned of designing and piloting these resources and his perception of their impact on students' learning was also investigated.

The resulting research question that was developed based on this aim was:

What was the experience and perception of first year chemistry students at Dublin Institute of Technology (DIT) of their learning environment when online pre-lecture resources designed to reduce cognitive load were implemented - and what was their lecturer's experience of the design and implementation of these resources?

Objectives

The objectives of this study have been formulated as research sub-questions and are presented below.

Sub-questions

Creswell (2003) recommends that several sub-questions be written for the central research question posed. I have broken my main question down into three sub-questions, shown below, which are ranked in order of the importance attributed to them during this study;

- What are the variations in learner experience of using the online pre-lecture resources in introductory chemistry at the Higher Education Institution being studied?
- What are the qualitatively different ways in which students perceive their learning environment for the introductory chemistry module?
- How do the learners' perceptions of their use of the online pre-lecture resources compare with those of the academic who designed the learning modules?

In addition, two considerations that will be borne in mind when undertaking the literature review and discussing the implications of the project for practice are as follows;

- How can a module be restructured to optimise consideration of the working memory model and do the changes required reduce the breadth / scope of the module syllabus?
- What are the perceptions of and reflections of the two researchers involved on the collaborative approach adopted for this project?

Ethical Issues

Students' names were not required to be provided on the surveys undertaken so they were anonymous. In addition, care has been taken in regard to the amount to information provided about student participants in interviews to ensure that their identity is not evident from that data. British Educational Research Association guidelines (BERA, 2004) were followed and the requirements are that the work:

- complied with the principle of voluntary informed consent by supplying information before gathering data from participants on the nature of the project, the role therein of the data relating to them and how it will be used and reported;
- avoided deception by providing explicit details on the role of the research and contacts for more information;
- informed participants of the right to withdraw at any time;
- did not provide incentives for completing questionnaires or participating in the research[1];
- ensured there was no detriment arising from the research because of participation – this was achieved by removing names from the data set where necessary once it was compiled;
- secured anonymity and did not name or identify by inference any student in the research.

The information sheet prepared about the research and the consent form circulated to the student cohort are presented in the Appendix.

One other issue that had been a concern was whether it would be necessary to seek permission from the parents or guardians of students who are under 18. Burton, Brundrett and Jones (2008:57) quote from several sources including BERA (2004:7) to establish that this is not necessary when; 1) the participant is judged to be competent and to have the capacity to decide about participation and 2) once the actions involved will not have an adverse effect on the subject.

The DIT Ethics Committee Guidelines for Taught Students state that, '*The DIT Research Ethics Committee does not normally consider undergraduate or taught postgraduate research or dissertation projects which come within the responsibility of the Head of School.'* The only exception noted is '*in circumstances in which the project raises ethical questions or poses a potential risk, or where there is some uncertainty as*

[1] A book voucher to the value of 15 euro was provided to compensate interview participants for their time. This was judged to be an appropriate way of acknowledging their input.

to the above'. For this reason, it is judged sufficient to inform the Head of School about the research project and the relevant ethical considerations and to seek his permission to undertake the work outlined.

Limitations

One limitation for the work was that it was only possible to interview 9 students to allow the research project to be completed within the given timeframe.

In addition, as this research project examined how students perceive their learning environment and how that is affected by pre-lecture resources designed to reduce their cognitive load, the conclusions from the research are localised to first year chemistry undergraduates on level 8 courses in Dublin Institute of Technology. However, these results should be useful in informing similar projects in other colleges or larger scale investigations across several higher education institutions.

CHAPTER 2

Literature Review

This chapter outlines current theories and discourse that are related to the research question and contributions from key authors in the relevant areas are presented. The chapter begins with a short introductory paragraph on widening participation and then the four main topics of concern to this research are examined; the effect of cognitive load on learning, the use and effectiveness of pre-lecture resources, studies on students' perceptions of their learning environment and collaborative educational research.

Widening Participation and "Scaffolding" for Learners

The agenda of widening participation in third level education has been to the forefront of government policy in most developed countries for over a decade now (David, 2010). It has involved increasing the number of places available and also employing strategies designed to increase the number of participants from under-represented groups (Childs & Sheehan, 2009). This has resulted in the type of students entering higher education changing over the past decade and, as a consequence, a requirement to change the teaching and learning strategies employed to accommodate these students (Cottrell, 2001; Johnstone, 2010). The recommended changes in approach are often termed "scaffolding", as the aim is to provide additional learning support (online and/or face-to-face) to that provided in the past to first year undergraduates and to gradually remove it over the course of that year with the expectation that students will have developed into independent learners by that stage (Childs, 2009; Mc Donnell & O'Connor, 2005 and 2007; Brouwer, Byers & Mc Donnell, 2005).

The Effect of Cognitive Load on Learning

Models of Information Processing

The way in which new information is assimilated has been studied by educational psychologists for some time and several reviews have been published (Ayres & Paas, 2009; Artino, 2008; Baddeley, 2003; Sweller and Chandler, 1991). This area of research has also informed science (St. Clair-Thompson & Botton, 2009) and chemistry education researchers (Johnstone, 1997; Reid, 2008). A model of how information is processed that was developed by Reid and Johnstone is presented in Figure 2. It shows that new information must (i) first be perceived as such and can then (ii) be processed in the working memory, which has a limited capacity, and, (iii) under the correct conditions, will then be assimilated in long term memory. According to Reid (2009), working memory in a science education context is probably best defined by Johnstone (1997) as:

> *a shared holding and thinking space where new information ... consciously interacts with itself and with information drawn from long term memory store in order to "make sense"*
> (Johnstone, 1997:263).

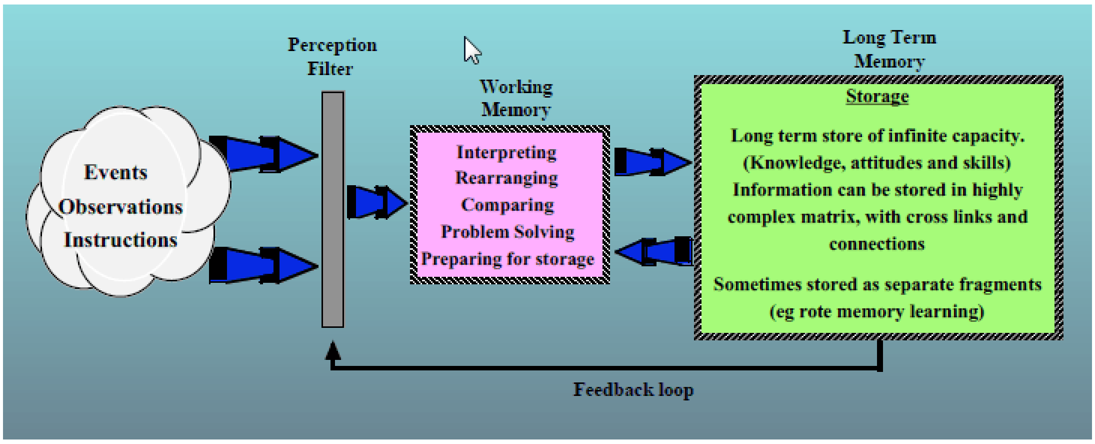

Figure 2: An Information Processing Model (reproduced from Reid 2008 and after Johnstone 1997)

Two theoretical approaches to working memory have developed as a result of psychology research. One is a unitary model which is often based on the concept of mental capacity and is associated with the work of Pascual-Leone (1987), while the other is a multi-component model which is linked to research by Baddeley and Logie (1999). The concept of working memory as a unitary system is the one used most often in science education to date. It is postulated that there is a balance between processing and storage tasks and that working memory overload can result because of either processing or storage demands (Just & Carpenter, 1992; Turner & Engle 1989). According to the multiple-component system model (Baddeley 2002; Baddeley and Logie, 1999), working memory has a central manager that coordinates performance on separate tasks and switches between them. These tasks are retrieval of information, removal of irrelevant information and storage and manipulation of information from the long-term memory. The central manager is supported by two storage components; the phonological loop which handles auditory information, and the visuospatial sketchpad which deals with visual and spatial information. St Clair-Thompson and Botton (2009) outline both of these theoretical approaches in a recent article and discuss the degree of consistency and divergence between them as well as the implications for future opportunities in science education research in relation to the multi-component model.

Factors Affecting Information Processing

The factors that influence how information is processed in the model proposed by Reid (2008) and Johnstone (1997) are highlighted in Figure 2.2. It can be seen that field dependency is an individual characteristic that affects a learner's ability to identify the important new information presented. This characteristic has been referred to as distinguishing the "signal" (what matters) from the "noise" (what is supplementary or peripheral) by Johnstone and Al-Naeme (1991). In addition, as working memory capacity is finite, when it is exceeded, a situation described as cognitive overload or working memory capacity overload results. Reid (2008) argues that this means that learning, seen in terms of understanding, effectively does not occur when working memory is overwhelmed with too much information and / or processing requirements. It has also been established that the existence of a relationship to previous knowledge and to experience (*i.e.* a context) is valuable in assisting the transition of information to long term memory (Reid, 2008; Ausubel 1968).

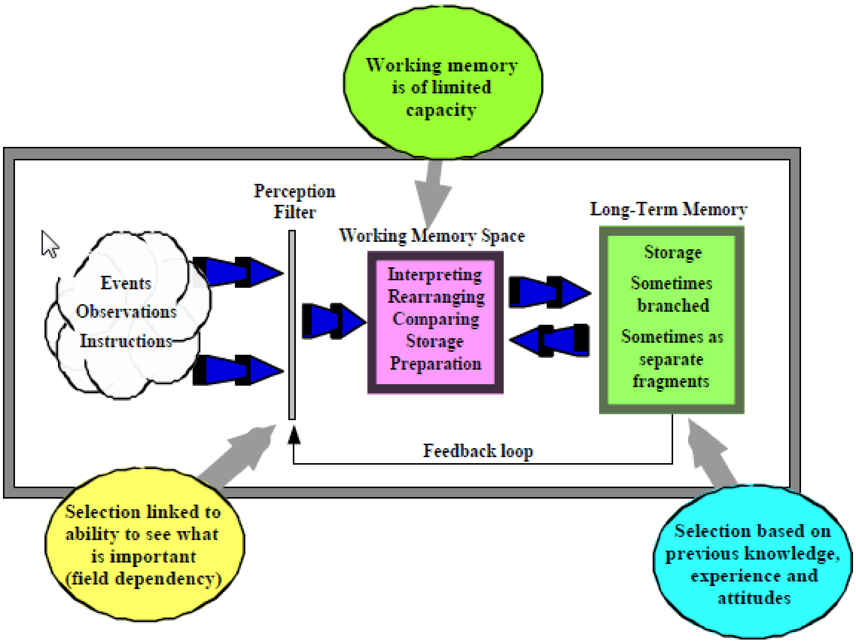

Figure 3: Factors that affect working memory capacity. (reproduced from Reid 2008)

Assessment of Field Dependence and Working Memory Capacity

In an education context, Field independence has been defined as the ability to select what is important for the task in hand from that which is not (Hindal, Reid & Badgaish, 2009). The extent of field dependency is often assessed using the group embedded figure test (Witkin, Dyk, Paterson, Goodenough, & Karp, 1974). Working memory capacities are often assessed using the figural intersection test (Pascual-Leone 1970) and / or the digits backwards test in which participants are presented with a series of digits and asked to recall them in reverse order (Wechsler 1955). The application of these tests in science and chemistry education has been reviewed by St. Clair-Thompson and Botton (2009) and Hindal, Reid and Badgaish (2009) respectively.

Investigation of Working Memory Capacity / Cognitive Load Effects in Science and Chemistry Education

Johnstone and Reid have both made significant contributions to the application of cognitive load and working memory models to teaching and learning science and chemistry and each have recently written reviews that bring together the main themes from this work (Johnstone, 2010; Reid, 2008, 2009). A number of studies in science and mathematics have shown that a relationship between the extent of field dependency and working memory capacity is usually found (El-Banna 1987; Al-Naeme 1988; Danili 2001) and this is often manifested by the field independent learner being able to select what is important more effectively and therefore not overloading their working memory.

Jung and Reid (2009) have examined the relationship between working memory capacity and attitudes towards science among secondary school students and found that there was a correlation between working memory capacity and attitudes to their studies in science. In particular, students with low working memory capacities tended to have more negative attitudes towards learning science. This finding was then used by the authors as an argument to re-examine curricula in order to ensure that the most difficult and inaccessible topics are not introduced until later stages. Overton and Potter (2011) recently compared how students approach context-rich, open-ended problems to how they solve structured, algorithmic problems. They found that field independence was important to success in the former but not the latter and that working memory capacity was found to correlate to achievement in both types of problem.

The Use and Effectiveness of Pre-Lecture Resources to Reduce Cognitive Overload

Pre-lecture Resources for Chemistry (Paper-based)

As was discussed in the introduction, learners who enter third level Science courses without having studied chemistry at second level often struggle to deal with the significant amount of new terminology, symbolism and concepts they are presented with (Childs and Sheehan, 2009; Johnstone, 2000; Seery, 2009b). One of the strategies that can been implemented to address this problem is to provide learning materials in advance of the lecture with the aim of then reducing the cognitive load experienced by students during their lecture. While there are numerous examples of the development of pre-laboratory tasks in chemistry education (Bennett, Seery, & Sovegjarto-Wigbers, 2009; Johnstone, 1994), the use of pre-lecture material is not as well established. Kristine reported the use of pre-lecture work to encourage students to study a topic prior to lectures and followed up in the lecture by discussing the concepts and implementing in-class tests (Kristine, 1985). He reports that students liked the pre-lecture work and that they felt it facilitated much greater in-class discussion.

More substantial work in this area which conclusively demonstrated the benefit of pre-lecture work was carried out by members of the Centre for Science Education in Glasgow led by Alex Johnstone and Norman Reid. These researchers were seeking to address a situation where incoming students had a diverse range of prior knowledge of chemistry. They defined the pre-lecture as an activity prior to a block or unit of lectures aimed at either establishing the essential background knowledge so that learning takes place on a solid foundation and/or stimulating the prior knowledge that may be present but inaccessible/forgotten (Sirhan, Gray, Johnstone, & Reid, 1999). In this paper and in subsequent work (Sirhan & Reid, 2001, 2002), the authors described how they used "Chemorganiser" worksheets that introduced key terms as pre-lecture activities. These were designed with the intention to support students' "chunking" of information so that they could familiarise themselves with the strategies for approaching a particular topic in one unit approach, rather than viewing a problem as several independent tasks, each one requiring a component of working memory. The results were very significant. When the pre-lecture resources were used with students who had little or no prior knowledge only, there was no significant difference between the exam marks of this cohort of students and the group who had prior knowledge of chemistry. When the pre-lectures were removed, a significant difference between the results returned. A research study at Dublin Institute of Technology also demonstrated the effect of prior knowledge of chemistry as it was found that there was a significant difference between the examination achievement in first year of chemistry students who had and had not studied chemistry at second level (Seery, 2009b).

Pre-lecture Resources for Chemistry (Web-based)

The development of electronic resources incorporating the principles of cognitive load theory can be used as a strategy to reduce the burden on the working memory of novice learners. Collard and co-workers have used this approach in chemistry in a process aimed at encouraging students to engage with their text book prior to the lecture and their students reported that the resources helped them to understand when in lectures more effectively (Collard, Girardot and Deutsch, 2002). The use of pre-lecture quizzes to identify areas of difficulty to be addressed in the chemistry lecture has been described by Slunt and Giancarlo (2004). Crippen and Brooks (2009) examined how best to incorporate the principles of cognitive theory into the development of chemistry web resources, but not specifically pre-lecture ones. They give details on the use of worked examples to scaffold students' learning. Their recommendation was that closed-ended, structured, interactive worked examples are best for novice learners.

Pre-lecture Resources for Other Disciplines

In other disciplines, pre-lecture work involving text books has been applied in the teaching of psychology students (Lineweaver, 2010). Also in the field of psychology, pre-lecture quizzes with the purpose of identifying areas of difficulty that can then be dealt with in the lecture have been implemented (Narloch, Garbin, & Turnage, 2006). Examples have also recently been reported for pre-lecture activities in biology and physics. The pre-lecture activity in biology was an extra lecture each week which all students, particularly those without a background in biology or unable to define a list of terms given to them in advance of the week's lectures, were encouraged to attend (Burke da Silva 7 Hunter, 2009). The physics initiative involved using pre-lecture resources which had the explicit intention of reducing the in-lecture cognitive load. Students were awarded credit for completing these resources (Chen, Stelzer, & Gladding, 2010).

Learner Difficulties in Relation to Scientific and Chemical Terms

For a learner with no prior knowledge of a scientific subject, dealing with the many new terms they encounter is often a considerable challenge. It is recognised that very specific and precise meanings are given to the terms used in scientific disciplines (Itza-Ortiz, 2003; Osborne & Wellington, 2001; Seery, 2009b). Many of the terms are derived from classical Latin and Greek, languages which the majority of today's students are not familiar with (Layson, 2009, 2010). In addition, some familiar terms often have other meanings when used in a scientific context. As an example, Jasien (2010) carried out a study in which learners in chemistry were asked to identify which of three possible contexts the word "neutral" was being used in for several sentences presented. In a study that examined second level physics textbooks, Merzyn (1987) found that they contained 2,000 technical terms and that 8 new words were introduced per class session on average. In fact, this number was found to be greater than the average number of new words introduced in a foreign language lesson. Although this type of analysis of chemistry textbooks has not been reported, it is to be expected that similar results would be obtained. Thus, the role that pre-lecture resources can play in supporting novice learners by helping them to assimilate the new terms they encounter is a significant one.

Students Perceptions of Their Learning Environment

There have been numerous studies in the education research literature, some qualitative and some qualitative, that have examined learner perceptions of their learning environment. A number of these, particularly those that relate to science and chemistry education will be discussed, as will the seminal work that underpins them.

Perceptions of Learning Environments in Chemistry

The Higher Education Academy recently produced a review of the student learning experience in chemistry in the United Kingdom (Gagan, 2009). This document summarises the data gathered from questionnaires circulated to students and staff in higher education institutions across the United Kingdom. The student responses showed that the nature of their learning experience appeared not to differ much across institutions. They rated tutorials as the most effective teaching method and practical work as the most enjoyable one. In addition, one third of students reported that they used the learning outcomes they had been provided with regularly and almost half would prefer to see more emphasis on continuous assessment. This type of quantitative analysis of student perceptions cannot provide data that is specific to a given situation but it is useful in generating an overall picture of the learning environment in the United Kingdom for chemistry at third level. Dalgety and Coll (2005) performed a smaller scale mixed methods study at a New Zealand university to investigate first year student perceptions and learning experiences. They administered a Chemistry Attitudes and Experiences questionnaire at two stages over the academic year and carried out semi-structured interviews with a sample of 17 students. Among their findings, they reported that students disliked a lecturing style which involved being provided with a complete set of notes at the beginning of the year, that they enjoyed tutorials and that they had mixed opinions about their laboratory practicals. Reardon, Traverse, Feakes, Gibbs and Rohde (2010) have examined the effectiveness of the Chemistry Course Perceptions questionnaire and compared it to another survey instrument, the General Self-Efficacy Scale.

Most other studies in chemistry education have dealt only with the learning experience in the laboratory. Domin (2007) used a mixed methods approach to compare student perceptions of problem-based and traditional laboratory instruction and found that conceptual development occurred during the laboratory session for the problem-based approach and afterwards for the traditional approach. Lyall (2010) examined a switch to a less structured laboratory programme and found that student learning and attitudes were improved as a result. Daly and Bodner (2005) report on a phenomenographic study that compared student perceptions of two learning environments, one formal (the laboratory) and one informal (a science museum).

Perceptions of the Learning Environment and Approaches to Learning

Particular perceptions of the learning environment, rather than the actual context or learning environment can strongly influence students' approaches to learning. Enwistle and Tait (1990) have observed, for example, that students who usually rely on a surface approach prefer lecturers who provide information that is ready to be learned and rate them more highly. However, students who tend to take a deep approach favour lecturers who challenge and stimulate their assimilation of the material (Entwistle & Tait 1990).

Approaches to learning have been classified into three categories that are usually observed; surface, strategic and deep. The original work that identified the concept of approaches to learning and which included descriptions of what were later labelled as surface and deep approaches was carried out by Marton & Saljo (1976a, 1976b). An additional category of the strategic (or "achieving") approach was later added as a result of further research in the area (Biggs, 1979; Ramsden & Entwistle, 1981). Table 1 below summarises the main characteristics of each approach. Further details on this subject can be found in the review on approaches to learning in Irving (2010).

Approach to Learning	**Surface**	**Strategic**	**Deep**
Main Characteristics	Sees the task as a demand to be met if some other goal is to be reached (e.g. a qualification).	Can adopt either a deep or surface approach depending on which is perceived to give a higher grade.	Is interested in the task and derives enjoyment from carrying it out.
	Sees the aspects or parts of the task as unrelated to each other or to other tasks.	Intends to obtain highest possible grades.	Personalises the task, making it meaningful to own experience and to the real world.
	Is concerned about the time the task is taking.	Organises time and distributes effort to greatest effect.	Integrates aspects or parts of task into a whole and sees relationships between this whole and previous knowledge.
	Relies on rote-learning, attempting to reproduce the surface aspects of the task.	Uses previous examination papers to predict questions.	Tries to theorise about the task, forms hypotheses.

Table 1: Characteristics of Surface, Strategic and Deep Approaches to Learning (based on Leung and Kember (2003) and Richardson (1993))

A number of studies have examined the relationships between approaches to learning and perceptions of the learning environment. A perception of a high workload in the tasks that students are assigned to complete has been linked to the use of a surface approach by students (Kember 2004, Entwistle & Ramsden 1983) and Birenbaum and Rosenau (2006) found that the perception of poor teaching and poor student teacher interpersonal relationships resulted in students adopting a surface approach to learning. It has also been established that there is a relationship between teachers' approaches to their teaching and students' approaches to their learning. Trigwell, Prosser and Waterhouse (1999) showed that students are more likely to report that they adopt a surface approach to their learning in classes where teachers describe their approach to teaching as having a focus on transmitting knowledge. In the classes where students described adopting deeper approaches to learning, teaching staff report adopting approaches to teaching that are more directed to students and to changing the students' conceptions. Entwistle, Mayer and Tait (1991) and Biggs (1985) have reported evidence of students having confused perceptions of the learning environment and also a lack of clarity in relation to the link between their perceptions of the learning environment and their approaches to their learning. They propose that these students may not reflect upon their studies and may lack an understanding of their learning environment. An investigation performed in the School of Physics at Dublin Institute of Technology into the problem-based learning environment for introductory physics students (Irving, 2010) demonstrated that the approaches to learning identified in that context were related to the level of awareness of the reasons for using a problem-based learning environment.

Collaborative Educational Research

It proved difficult to find literature on this area as the focus when reporting on collaboration in educational research is on that which occurs between the researcher and participants who are the subject of their research and on collaborative learning between students. However, based on empirical evidence, I feel that collaborative research is occurring to a significant degree in the field but it has not been an aspect that has been concentrated on when reporting and discussing research findings. Berglund, Box, Eckerdal, Lister and Pears (2008) describe their involvement in a computer education research group which collectively learned an educational research method, phenomenography, through collaborative research. This was achieved by organising two phenomenography workshops for which the emphasis was on preparing a joint publication as a result of each one. One conference paper written examined the experience of being a computer science lecturer and the other concentrated on lecturers' experiences of the problems their students come up against when learning computing. (Pears, Berglund, Eckerdal, East, Kinnunen, Malmi, McCartney, Moström, Murphy, Ratcliffe, Schulte, Simon, Stamouli & Thomas, 2008). Data was collected in advance of the workshop by each participant and initial transcript analysis took place at the workshop. A similar approach was taken by a Europe-wide working group in chemistry education to prepare a book on innovations in teaching and learning chemistry in higher education. An account of the process involved in preparing the book has been published but the collaborative education research aspect, although apparent, is not specifically addressed (Eilks & Byers, 2010). An example involving collaboration between two researchers is provided by McGarrigle (2009) who undertook a case study on a community-based learning module and describes how his research, which focussed on how the students learned collaboratively and developed their ideas about community, complemented that of his colleague who was investigating the engagement that was occurring between these learners and the community partners (Hand, 2009).

Collaborative Action Research

In action research however, collaboration in the form of a critical friend is well-documented. A critical friend, also called a 'critical colleague' or 'learning partner' is someone whose opinion the researcher values and who will be able to critique their work and help them to see it in a new light (Mc Niff, 2010).

Collegiality

Wieman (2006) has written on the need for collegiality and collaboration among science lecturers in relation to their teaching as well as their research and recommends that staff work in teams to generate educational goals and learning outcomes and then go on to develop materials and assessment tools collectively. He contends that if teaching is allowed to be maintained as an individual activity that inefficiencies due to reinvention will remain. He recommends an approach similar to that used in science research in which researchers build on advances made by their predecessors and remarks that:

> *Through this process they achieve results far beyond the capabilities of any single person. There is no reason why the teaching of science cannot be as successful as the practice of science in this regard.*
>
> (Wieman, 2006:12)

CHAPTER 3

Research Design

As already described in the introduction, the basis of this research was the investigation, using predominantly qualitative means, of the effect of online pre-lecture resources developed by a colleague on students' perception of their learning. This chapter is concerned with how the research question identified could be investigated. The theoretical framework selected (epistemology, theoretical perspective, methodology and methods) will be discussed and their appropriateness to the research context justified. This will be followed by a consideration of the data collection and analysis methods used.

Epistemology

An epistemology is a view of knowledge, a philosophical assumption about how people obtain knowledge. Crotty (1998: 3) defines an epistemology as a '*way of understanding and explaining how we know what we know*'. The three main epistemological positions are objectivism, subjectivism and constructivism. Constructivism holds that knowledge arises from our engagement with the realities around us and that meaning is constructed. This leads to the assumption that it is possible that different people will construct knowledge in varying ways. Thus, both subject and object are involved in making meaning (Crotty, 1998). The research question that I have chosen takes the constructivist viewpoint as it deals with investigating how individual students approach their learning and with understanding how they perceive their learning environment.

Theoretical Perspective

Interlinked with the three main epistemologies, there are three major theoretical perspectives that could be applied to undertake this research project. They are the positivist, interpretivist and critical paradigms. The theoretical perspective chosen provides the philosophical stance that will underpin the methodology to be used as well as a context for the research process (Crotty, 1998). The paradigm found to provide an appropriate framework for my research question is interpretivism. Positivism and post-positivism can only be supported by an objectivist epistemology (Crotty, 1998) so they were rejected on that basis. Critical theory seeks to understand but also to transform a situation but my research question wants to arrive at an understanding and it does not seek to change.

Interpretivism

The interpretivist paradigm developed as an alternative to positivism (Cohen, Manion and Morrison, 2000; Crotty, 1998) and is often related to the work of Max Weber who postulated that social science research revolves around understanding (Crotty, 1998). Cohen *et al.* (2000:23) state that interpretive researchers 'begin with individuals' and that the aim of research undertaken in the interpretive paradigm is to understand and describe the interpretations by individuals of the world around them; 'the subjective world of human experience' (Cohen *et al.*, 2000:22). Travers (2001) describes how the aim of the interpretative approach is to look at how people understand their own actions. Interpretive researchers work directly with experience and understanding to develop a theory and the interpretivist approach holds that any event can be perceived in multiple ways and that reality is complex.

Investigating how individual students approach their learning and how they view their learning environment is best incorporated in the interpretivist paradigm. Some of the theoretical assumptions associated with the interpretivist paradigm are that meaning is constructed by individuals as they engage with the world they are interpreting (Creswell, 2003); that research will be small-scale and will be interpreted in a particular context rather than generalised and that theory is developed inductively from the data collected (Cohen *et al.*, 2000; Creswell, 2003). These assumptions can be appropriately applied when seeking to describe and understand the interaction of learners with their course material and learning tools and how they perceive their learning environment. Cohen *et al.* (2000) comment that interpretivism often appeals to educational researchers as it maintains the integrity of the situation in which it is used because the influence of the researcher in organising, analysing and interpreting the event is minimal. Rex, cited in Cohen *et al.* (2000:26), points out however that an objective perspective on an event is often essential and that social reality should not be based solely on descriptions by the participant actors. Another shortcoming of the interpretive paradigm is that it largely neglects the effect of external forces on behaviour and events (Cohen *et al.*, 2000).

Methodology and Methods

A methodology is defined as a strategy or plan of action that connects methods to outcomes (Crotty (1998); Creswell, 2003). Crotty (1998) maintains that any paradigm can make use of any methodology and that any methodology can make use of any method. He qualifies his remark by saying that, in all cases, this is only feasible if the particular selection suits the purposes of the research. In practice, there are particular methodologies that tend to be associated with certain paradigms and methods with methodologies but, as Crotty (1998) has indicated, there is some flexibility. As the research question being examined is framed in the interpretivist paradigm, the associated methodologies considered were grounded theory, ethnography and phenomenography (Crotty, 1998). Phenomenography is the methodology that has been selected for this research design as it was judged to be the most appropriate choice to allow the research question to be answered.

Phenomenography

This methodology '*focuses on identifying and describing the qualitatively different ways in which people understand phenomena in the world around them*' (Franz, Ferreira and Thambiratnam, 1997). It was developed in the 1960's and 1970's by Marton and his follow researchers as an approach for examining student learning (Tight, 2003). Marton, quoted in Tight (2003: 197), defines phenomenography as;

> *..the empirical study of the limited number of qualitatively different ways in which various phenomena in, and aspects of, the world around us, are*

experienced, conceptualised, understood, perceived and apprehended.

The aim is to describe the variation in experiences of a phenomenon across a group by arriving at categories of description:

> *... it aims to describe the key aspects of the variation of experience of a phenomenon rather than the richness of individual experiences, and that yields a limited number of internally related, hierarchical categories of description of the variation.*
> (Trigwell, 2000:77).

Thus, phenomenographic outcomes do not show the richness of the data, only variation, for which there is clear evidence from the transcripts (Bowden, 2005).

Why use phenomenography?
This methodology can be applied when;

- The perspective and experiences of the learners, not the researcher, is of interest (second order perspective).
- The different ways that participants experience a phenomenon is being investigated, and the researcher is of the opinion that that phenomenon can be experienced in a variety of ways.
- The researcher wants to determine which features of a phenomenon should be examined further (Orgill, 2007)
- It is hoped to use the findings to plan future learning experiences and to develop generalisations about how to organise learning experiences in the discipline concerned (Bowden, 1996).

There is a distinct resonance between the research aims and underlying assumptions of phenomenography and those expressed and implied in my research question and this is why phenomenography was the methodology selected. The aim of this methodology is to increase insight and to understand and describe the limited number of qualitatively different ways in which a phenomenon is perceived and experienced. In the context of this research design, the phenomena under study are the learning environment of the chemistry undergraduate participants and the online pre-lecture resources. Further support for the selection of phenomenography comes from an analysis of the research questions described in the literature that have been previously addressed using this methodology. Studies of student perceptions of their learning environment in chemistry by Domin (2007) and Daly and Bodner (2005) and in physics (Irving, 2010) which were referred to in the literature review used a phenomenographic methodology and they have similar themes and concerns to the research question posed in this study.

Developmental phenomenography rather than "pure" phenomenography is the approach used in this research. In developmental phenomenography, the purpose of the research is to use the outcomes to help the participants or others like them to learn. The outcomes can be used to plan learning experiences and to develop generalisations about how to organise learning experiences in the field concerned. This means that the focus of the research is on the participants as much as it is on the phenomenon being examined. (Bowden, 1996; Bowden and Green, 2005; Akerlind, 2005).

Conceptions and categories of description

Bowden (1996) and Sandberg (1997) describe the relationship between individual 'conceptions' and 'categories of description' and emphasise that the two should not be used interchangeably. It is proposed that the term conception, from a phenomenographic perspective, is used to denote people's ways of experiencing a particular aspect of reality (*i.e.* a phenomenon). Conceptions are usually *presented* in the form of categories of description. Categories of description should be as faithful as possible to the individuals' conceptions but are not asserted to be equivalent to them as they are based on an analysis of the collective experience. Thus, a conception is an intangible entity and a category of description provides a concrete way of describing it (Ireland *et al.*, 2008). Bruce (2003) has described a conception diagrammatically as the relationship between the subject and the phenomenon experienced as shown below in Figure 4.

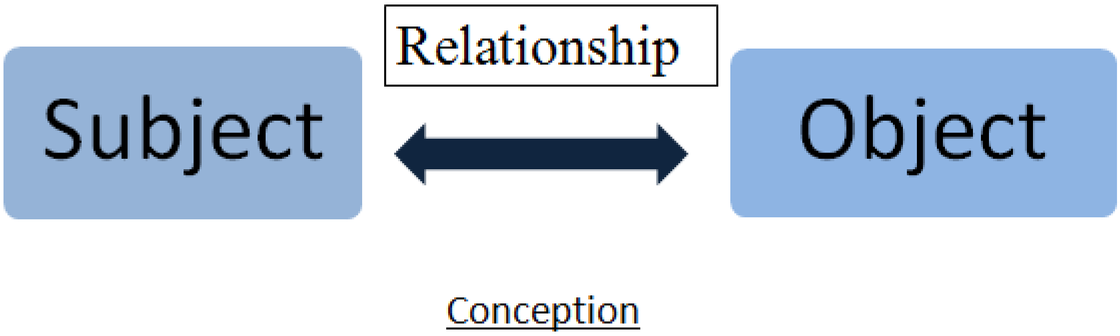

Figure 4: Graphical representation of a conception (based on Bruce 2003)

Generation and evaluation of outcome spaces

Once the categories of description have been established, relationships between them are then considered and they are usually arranged in the form of a hierarchy from less to more comprehensive called the outcome space (Akerlind, 2002). The hierarchy does not have to be linear and can be branched. The hierarchy doesn't represent value judgements (better or worse) but some categories of description will be inclusive of others (Akerlind, 2005). The result is that the researcher is seeking to establish more than a set of different meanings as the goal is to produce a logically inclusive structure that provides a relationship between the different meanings (Akerlind, 2005). The claim made is that the research outcomes collectively describe the entire range of possible ways that the particular phenomenon being studied can be experienced, at the point in time when the study was carried out and for the population represented by the sample group. The focus on a collective experience means that phenomenography holistically examines the range of experiences in a sample group, as a group, and not for each participant in the group. Each transcript is interpreted within the context of the group of transcripts by examining differences from and similarities to other transcripts (Akerlind, Bowden & Green, 2005).

Three main criteria for assessing the quality of a phenomenographic outcome space have been proposed by Marton and Booth (1997);

1. Each category in the outcome space should tell us something distinctive about a particular way of experiencing the phenomenon;
2. The categories should have a logical relationship to each other, usually as a hierarchy of structurally inclusive relationships; and
3. The system should be parsimonious, i.e. that the critical variation in experience found in the data should be captured by a set of as few categories as is feasible and reasonable.

Frameworks for studying experiences and conceptions

Two analytical frameworks have been developed to analyse experiences and conceptions of phenomena. The first distinguishes between how and what aspects. Thus, for the example of the experience of learning, the how aspect denotes the learner's approach in achieving his or her task and the what aspect refers to the direct object of learning (Marton and Booth, 1997). The how aspect can be broken down further into the act of learning and the indirect object of learning. The act of learning refers to *"the experience of the way in which the act of learning is carried out"* (Marton & Booth, 1997) and the indirect object of learning refers to the goals that the learner is trying to achieve (*i.e.* their motives). This framework encourages researchers to consider what is being understood as well as the process, actions and motives that underpin this understanding when analysing data (Harris, 2011).

The second framework differentiates an individual's experience or conception into structural and referential dimensions. This approach allows parts and contexts to be identified. The structural aspect comprises "discernment of the whole from the context [external horizon]" (Marton & Booth, 1997:87) as well as "discernment of the parts and their relationship with the whole [internal horizon]" (Marton & Booth, 1997:87). The referential aspect denotes the meaning participants attribute to a phenomenon. This framework prompts researchers to contextualise participant's conceptions and experiences and examine the components that comprise them (Harris, 2011). In this work, the how and what aspect was used during the analysis but ultimately the outcome space developed was framed using structural and referential dimensions.

Harris (2011) conducted a review of the application of these frameworks in 56 phenomenographic studies and concluded that, although they are not strongly grounded in theory, when they are clearly defined, they increase the rigour and depth of data analysis. She proposes that the frameworks should be considered as "tools, providing researchers with a way to 'think apart' intertwined understandings, processes, parts, motives, and contexts." (Harris, 2011: 117). However, she notes that achieving these additional levels of meaning is dependent on data collection that has specifically probed for these facets and emphasises that the frameworks have limits and are unlikely to be capable of analysing all of the complex features of a person's conceptions of multifaceted phenomena.

Methods

Cohen *et al*. (2000) define methods as strategies for data collection and researching. They can be classified as being quantitative if they are predetermined and involve measuring and counting and statistical analysis. Qualitative methods emerge during a study and necessitate gathering data in interviews, observations, documents and audiovisual material. Text and/or image analysis is required (Creswell, 2003). Crotty (1998) draws attention to the fact that his framework for research design does not address the distinction between quantitative and qualitative research until the level of methods is reached. He disagrees with the approach of many textbooks where a divide between objectivist research which is coupled to quantitative methods and constructivist or subjectivist research which are coupled to qualitative methods is identified as one of the main ways of categorising research. Crotty (1998) defends this stance by pointing out that research can, and often does, involve both qualitative and quantitative methods but it is maintaining the distinctions between different epistemologies and paradigms in a piece of research that is the issue.

Methods Used in the Context of This Project

Quantitative and qualitative methods were employed in this research design but the emphasis in this mixed methods study is on the qualitative aspect because a constructivist epistemology is informing the approach. Initially, a quantitative research phase took place and the results of this phase informed the planning of the second, qualitative phase.

Additional Aspects of the Research Design

A case study relates to an in-depth exploration of a single or small number of units and this unit may be a person, a process, an event or an organisation (Hancock, 2002; Creswell, 2003). Burton, Brundrett and Jones (2008) argue that a case study is not so much an approach to research as a definition of the scope and scale of the research project and I have applied this interpretation of a case study to this work. The scope of my research project is that it examines one cohort of students in one higher education institution and one new learner support strategy that has been introduced. Yin (2004) provides a similar interpretation of the case as the set of events that the data will be drawn from, in this instance the implementation of online prelecture resources for an introductory chemistry module, and of the case study as comprising the research questions, theoretical perspectives, empirical findings, interpretations and conclusions.

Yin (2004) asserts that in a case study, qualitative and quantitative data can be used as can a variety of data collection methods and Burton *et al.* (2008) concur that the concentration on depth rather than breadth entailed promotes a multi-method approach. Bruce (2006) has described phenomenography as a frame that can be viewed through different lenses. Thus, this research project is a case study that uses a phenomenographic frame and which is viewed through a constructivist lens and uses an interpretivist approach.

Data Collection

Quantitative Data Collection

In the quantitative phase, all students in the group being studied were asked to complete a Likert scale attitudes survey which was comprised of 35 statements. A copy of the survey is presented in the Appendix. Two questions on the first page related to the degree course the student was enrolled in and the science subjects they had studied at second level and a section for recording optional additional comments was included. The questionnaire was administered in a paper-based format. Some questions from the Colorado Learning Attitudes About Science Survey (Barbera, Adams, Wieman & Perkins, 2008) were included and permission to do so had been obtained from the author. One of the statements taken from this survey requested that "agree" be selected as the response and, if this was not done, it was assumed that the participant was not reading the questions. The survey was distributed twice to the entire student cohort; in the second week of the module and in the first week of the second semester when the module summative examination was complete to examine if any changes were observed. Once the data from the initial quantitative phase had been analysed, it was used to help inform the preparation of interview questions for the qualitative phase.

Qualitative Data Collection

The individual semi-structured interviews were performed with nine participants in the first four weeks of semester two. The students were selected by purposive sampling on the basis of providing a sample which would maximise variety among the participants and ensure that a range of experiences would be captured. Criteria used to do this included programme of study, prior experience of chemistry, leaving certificate performance, grade obtained in the Introductory Chemistry module, and sex. In addition, a mature student and a student with a registered learning difficulty were invited to participate. The range of students interviewed was not a statistical sampling but was wide enough to contain differences in ways of experiencing the use of the pre-lecture resources and the learning environment.

The open-ended questions that were prepared for use in the semi-structured interviews are presented in the Appendix. They were categorised into four areas; opening questions about prior knowledge of chemistry and internet access/technical difficulties, experience of using the pre-lecture resources, experience of cognitive overload and perceptions of the learning environment. Some of the questions were developed by reformatting survey statements as open-ended questions while others were adapted from existing studies which used phenomenography (Walsh, 2009) or qualitative methods (Thompson, Oakes & Bodner, 2005) to analyse student perceptions of their learning environment.

The interviews were semi-structured and the questions posed were open and sought to encourage participants to describe their perceptions and experiences in detail. Ashworth and Lucas (2000:302) provide guidance on how a phenomenographic interview should be conducted and state that "In essence, the interview should be regarded as a conversational partnership in which the interviewer assists a process of reflection." The phenomenographic approach requires that researchers adopt the role of neutral foil, referred to as bracketing. Ireland *et al.* (2008) recommend that "gentle enthusiasm" be used during interviews to put participants at ease and Shreeve (2010) expresses this in terms of the interviewer adopting the role of a conversational facilitator.

The researcher who was developing the online pre-lecture resources, Dr Michael Seery, agreed to be interviewed at the beginning of the semester following their implementation. He and I also set up a wiki dedicated to this research project to allow us to collaborate easily and to facilitate posting of our reflections to the learning / research diaries we have created there. Our research supervisor also had access to this wiki.

The fact that the researcher undertaking this part of the work was not a lecturer on the module was an important factor as it removed the possibility of a conflict of interest arising when the students' perception of their learning on the module and their experience of the pre-lecture resources were being probed.

Data Analysis

Analysis of Quantitative Data

The survey responses were collated according to whether respondents had studied chemistry before or not and which course of study they belonged to. Percentage selections to each of the five possible responses on the Likert scale for each statement were calculated. These results were used to inform the development of the questions for the interviews. When the survey was implemented for the second time, responses were compiled in the same way. The detailed results were entered into an Excel spreadsheet and the summary of the responses to each statement were compiled in a table.

The number of surveys completed did not allow for statistical significance to be drawn from the responses but the data did permit an overall impression to be developed of the attitudes to learning chemistry among the student cohort being studied at two stages in their academic year. It had been decided to make the surveys anonymous to ensure that students felt comfortable about responding honestly. This meant that individual surveys could not be analysed for any changes in attitude that developed from the pre- to post-module stage. However, the pre- and post-module average responses to each question were compared and, when a difference of greater than 10% was observed, this was noted.

Analysis of Qualitative Data

As there is no prescriptive format to conduct phenomenographic research, when phenomenography is used, it is essential that the procedure adopted is documented and the individual variations in the method used are explained (Bowden & Walsh, 2000).

The differentiation between critical and noncritical variation is important during phenomenographic analysis. Critical variation is described as "that which distinguishes one meaning or way of experiencing a phenomenon as qualitatively different from another" (Akerlind, Bowden & Green, 2005:82) and non-critical variation occurs within a way of experiencing and therefore does not distinguish between ways of experiencing.

Variation in the Amount of the Transcripts Considered During Analysis

Categorisation into categories of description is either done using entire transcripts or extracts from transcripts that are then combined for analysis in one decontextualised "pool of meanings" (Akerlind, 2005). Considering the entire transcript is proposed to give a holistic view (Bowden, 1996). Bowden *et al.* (1992:263) recommend that the focus should be on "the student's meaning, taking the transcript as a whole, rather than on the occurrence of particular statements corresponding to a specific category description." The arguments in favour of examining excerpts are that it makes the data more manageable and that the decontextualised approach ensures that there is a focus on collective analysis (Akerlind, 2005; Svensson & Theman, 1983). As this study is adopting the developmental phenomenography approach described by Bowden (1997, 2005), the entire transcripts were considered when establishing categories of description.

Timing of Consideration of Structural Relationships During Analysis

There is disagreement in the literature regarding the stage at which the search for structural relationships between meanings in order to develop the outcome space should begin. Some phenomenographic researchers emphasise that structure should not be sought too early in the process as it can distract from the appreciation of facets of the meaning that can be found in the data and can also introduce the researcher's relationship with the phenomenon into the categories (Bowden, 1996; Ashworth & Lucas, 2000). However, others warn that if structure is not taken into account until too late in the process that the meaning and structure will not be sufficiently co-constituted in the final outcome space (Akerlind, 2005). This work followed the method described by Bowden (2005) and the structural relationship between the categories of description was not be considered until the categories of description were finalised.

In many cases, phenomenographic researchers work individually during data analysis but it is often advocated that additional researchers should be involved to maximise open-mindedness (Trigwell, 2000). However, Akerlind (2005) acknowledges that it is unavoidable that all outcome spaces will be partial to some extent and that a study performed by a sole researcher can make a significant contribution to the understanding of a phenomenon even if group research may have extended it further. As this particular study is for a master's thesis, I worked alone during the data analysis. However, I was able to discuss emerging outcomes with my colleague who had designed the resources.

Validity

Validity is concerned with the degree to which a study is seen to investigate that which it is intended to investigate (Akerlind, 2005; Kvale, 2007). The significance of validity in qualitative research is captured by Gibbs (2007:91) who states that there may not be a simple absolute truth as in quantitative research but "there can still be error." These inaccuracies may be due, for example, to biased or incorrect descriptions and interpretations being provided. Two methods of checking validity, termed communicative and pragmatic validity (Kvale, 2007) are commonly used in phenomenographic research (Akerlind, 2005). Communicative validity, or "testing the findings of a study in a conversation" (Kvale, 2007:128), focuses on checking the coherence of a researcher's interpretation of the data *i.e.* of the knowledge claims made (Sandberg, 2005).

Three ways in which this can be achieved are;

(i) within the interviews when communicating with the subject;

(ii) during the analysis of empirical data (interview transcripts) by communicating with the aim of producing coherent interpretations and;

(iii) in communicating the findings to other researchers and professionals in the field. (Sandberg, 2005; Mann, Dall'Alba & Radcliffe, 2007).

Pragmatic validity examines the extent to which research findings are perceived to be useful and involves "testing the effectiveness of our knowledge by testing the effectiveness of our actions" (Kvale, 2007) as well as the degree to which they are meaningful to the intended audience (Akerlind, 2005).

In this study, communicative validity was achieved within the interviews, when analysing the transcripts and in communicating the findings to other researchers.

Reliability

Reliability relates to the consistency and trustworthiness of research findings and, in qualitative research, is often examined in terms of whether a finding is reproducible at other times and by other researchers. This can apply to replies given in an interview and also to transcription and analysis of the data (Kvale, 2007). There are two checks on reliability that are often used in qualitative, interview-based research; coder reliability checks and dialogic reliability checks. They are employed to varying degrees within phenomenographic research (Akerlind, 2005). An alternative to these checks that is often used to justify knowledge produced by interpretive approaches is that the researcher ensures that they have made their interpretive steps clear to readers by fully describing those steps and providing examples to illustrate them (Akerlind, 2005).

Sandberg (1997, 2005) has proposed that communicative and pragmatic validity together with reliability as interpretative awareness are suitable criteria for justifying knowledge produced within interpretive approaches. He describes how interpretive awareness involves the researcher documenting how they have analysed their own presuppositions and the controls and checks applied to counteract the influence of their perspectives on the research outcomes. Sandberg (2005:59) explains that "To maintain an interpretive awareness means to acknowledge and explicitly deal with our subjectivity throughout the research process instead of overlooking it." Stages where it is important to consider the possible impact of existing presuppositions include the devising of research questions, selection of participants, interviewing of participants, analysis of resulting transcripts and reporting of the final categories of description (Mann, Dall'Alba & Radcliffe, 2007). Therefore, in this study, I have endeavoured to show evidence of interpretive awareness at these stages.

Method of Interview Analysis

Transcription and formatting

An excel file containing the relevant metadata on each interview (date, participant details, participant code used in transcripts) was prepared. Transcription of interviews is a change of medium and it is important that it is ensured the transcripts are accurate (Gibbs, 2007). The interview recordings were transcribed verbatim by a professional and the transcripts were then checked for errors, unclear meanings and inconsistent statements and were then checked against the recordings. This process also allowed me to become familiar with the transcripts. The transcripts were formatted for easy reference and marking and it was ensured that they were anonymised. Therefore, the 9 interview participants were be identified as students A to I and the transcripts were printed with spacing and a half between lines and pages and lines have been numbered.

General aspects of reading and analysing the transcripts.

They were treated as a set as this gives a holistic view (Bowden, 1996). In relation to a given research question, an initial search for variation in meaning is performed across the transcripts by finding similarities and differences between them. A data-driven or open approach is applied (Gibbs, 2007) as the categories of description will emerge from the data and it is a process of discovery with no hypotheses formed in advance. This process is described as “bracketing”, the putting of presuppositions to one side (Ashworth & Lucas, 2000). The researcher remains neutral and the transcripts are the only source of evidence that can be used. Another consideration that is important is to concentrate on the transcripts and emerging categories of description as a set instead of individually so that a focus on the collective experience is preserved (Akerlind, 2005).

Ashworth and Lucas (2000) recommend listening to the transcripts during the initial stages of analysis to ensure that anything that may affect the interpretation of meaning is considered and this approach was taken in this case. Initial categories describing different experiences of the phenomenon are then developed. The analysis is iterative and requires constant comparison to ensure internal consistency (comparing similarly categorised transcripts to see if there is any variation). If this occurs, an alternative categorisation needs to be formulated. Categories of description continue to be reviewed and tested against the data (the transcripts) until no further adjustments are necessary. Categories of description are formed into an outcome space (a description of the ways of experiencing a phenomenon and how they relate to each other) by looking for referential and structural differences between categories.

Detailed description of interview data analysis process

This description draws from similar accounts by several other authors (Walsh, 2009; Irving, 2010 and Mann *et al.*, 2007).

The interviews provided data to answer the following research questions:

- What are the variations in learner experience of using the online pre-lecture resources in introductory chemistry at the Higher Education Institution being studied?
- What are the qualitatively different ways in which students perceive their learning environment for the introductory chemistry module?

In a phenomenographic study, the unit of analysis is a "way of experiencing" and it can also be expressed as a way of understanding, depending on the circumstances (Booth & Ingerman, 2008). It was necessary to analyse the transcripts using two different units of analysis in order to answer these questions as follows;

1. Learner conceptions of their experience of using the pre-lecture resources.

The focus in this case is on the qualitative variation in the ways that learners experienced using the pre-lecture resources at the higher education institution (HEI) being studied. Categories of description are formed based on the different experiences or meanings that students assigned.

2. Student perceptions of their learning environment.

In this study, the students' perception of their learning environment is taken to mean the participants' perception of how their introductory chemistry module was presented to them and of what is expected from them in their study of chemistry. The focus is on the qualitative variation in the ways that learners experienced the learning environment for introductory chemistry at the HEI being studied. Categories of description are formed based on different meanings (or conceptions) students assigned to their learning environment. Categories may be described using two components; how their environment is described and what is focussed on.

The analysis process involved repeated exposure to and immersion in the interview transcripts (repeated listening and reading, personal reflection, discussion with colleagues and writing about the text) while seeking to bracket my own personal biases and experiences throughout. In analysing the data, qualitatively distinct categories emerged that described the variations in the students' perceptions and conceptions.

Throughout the initial phase of examining the transcripts, it was attempted to maintain an open mind to any possible meanings and the transcripts were considered as a whole and within a collective context.

For each reading of a transcript (which also involved listening to the recording), I tried to focus on one particular aspect. For example, in the case of the first unit of analysis, on the variations in ways the learners experienced interacting with the pre-lecture resources, how they experienced the lecture that followed, the aspects of the pre-lecture resources they focussed on or the variation in ways they experienced pre-lecture resources on particular topics. After I felt I had sufficient familiarity with the data, I prepared a set of notes that recorded the information that I identified to be critical to the learners' experiences of using the online pre-lecture resources. These notes included concept maps to allow critical features of the experience to be represented diagrammatically and one to two pages were produced for each of the transcripts. While preparing them, I tried to bear in mind the how and what aspects within the transcripts (how is the pre-lecture resource experienced and what is focussed on?). In the next phase, I then worked with the notes and the transcripts to look for the critical similarities and differences between the transcripts. I added additional notes on cases of agreement and variation on what I perceived to be critical aspects.

It was then attempted to group transcripts and corresponding notes depending on the similarities and differences between them. During this process, difficulties with discerning which group a transcript should be placed in highlighted that critical variation existed within certain transcripts (i.e. if there was the possibility it could be placed in two groups). This required that the meaning of statements that were similar be investigated to establish their meaning and this was achieved by returning to the original transcript and reading some pages before and after the statement to examine the underlying intention. Mann *et al.* (2007:12) point out that during the process, "the researcher must constantly be asking, 'Is there another way of interpreting this statement?' ". During this process, I prepared a Microsoft Excel worksheet to record the similarities and differences between transcripts and I then began to describe them while referring back to the transcripts constantly.

From this, tentative categories were formed and, once this was achieved, the categories and transcripts were examined repeatedly for the structure of the categories. For each category that had been identified, I returned to the groupings of transcripts and notes to find cases of agreement and contrast within the transcripts. This process led to some categories being reconstituted and redefined to ensure that they described the variations in experiences of using the pre-lecture resources faithfully and empirically and was repeated until a set of internally related categories with a hierarchical structure that provided a holistic representation emerged. A label was developed for each category of description during this phase but it was important to wait to do this until late in the analysis as it can limit further category development (Bowden, 2005; Mann *et al*., 2007). The categories were then sorted onto a hierarchy based on their increasing comprehensiveness.

The focus was then shifted onto the next unit of analysis, the variations in the students' perceptions of their learning environment. The analysis was carried out in the same way as already described. The final stage of the process was to select excerpts and statements from the transcripts which I felt would give substance and support to the categories.

CHAPTER 4

Presentation and Discussion of the Research Findings

In this chapter, the findings from the analysis of the quantitative (questionnaires) and qualitative data (student and lecturer interviews) collected in order to answer the research question are addressed. These findings are presented making use of suitable tables, figures and interview excerpts. They are then discussed in the context of the research question and the relevant literature.

Quantitative Data - Survey of Student Cohort

The questionnaire on attitudes on learning chemistry was completed anonymously by 43 students in the second week of the college semester on September 30th 2010. The total number of students in the cohort was 49. Of the 42 surveys collected, 1 was discarded as it was incomplete and a further 3 were not included in the analysis as the response selected to statement 32 was not the one specified. Statement 32 requested that "agree" be selected as the response and, when this was not done, it was assumed that the participant was not reading the questions carefully (Barbera *et al.*, 2008). The data obtained from the 39 surveys analysed was used to inform the development of the questions for the semi-structured interviews with students.

The same survey was administered again in week one of the second semester on 3rd February. The Introductory Chemistry module that was the focus of this study was complete at this stage and students had taken the examination and received their results. On this occasion, 36 students completed the survey. Of these, 4 participants did not respond as directed to statement 32 and, therefore, 32 surveys were analysed. The two stages at which the students were asked to complete the survey have been labelled "pre" (week 2 of the first semester) and "post" (week 1 of the second semester) when presenting the data. The "pre" survey was implemented at the earliest stage at which it could be arranged to do so and was actually administered just after the innovation of interest, the online pre-lecture resources, had been first introduced to the students.

However, it does capture student attitudes towards the beginning of their Introductory Chemistry module.

The table prepared that captures all of the data from the surveys broken down in terms of degree course and whether students had studied chemistry at Leaving Certificate is provided in the Appendix. Table 2 presents a summary of the response data for a selection of statements that are particularly relevant to the research question. A version of this table that includes all of the statements from the survey is provided in the Appendix. In order to simplify the analysis, the percentage of 'agree' and 'strongly agree' responses were combined, as were the 'disagree' and 'strongly disagree' responses. Pre- and post- responses in each category ('agree/strongly agree', 'neutral' and 'disagree/strongly disagree') for each question were compared and, when a difference of greater than 10% was observed, both pre- and post data has been presented. When the difference was less than 10%, the overall average from the pre- and post- surveys is used. The number in front of each statement refers to the question number in the original survey and the statements have been reordered from there so that they are grouped into similar themes. Colour-coding (pink background) is used in the table to highlight statements for which the agree and strongly agree total came to over 60%. The survey addresses attitudes across a number of areas including context, pre-lecture information and multimedia tools and each will now be dealt with briefly in turn.

Statement on Attitude to Learning Chemistry from Survey	**Summary of Responses** (values are averages of pre and post responses unless noted otherwise)
9) It is important to know why I need to learn about a topic.	88% agree/strongly agree & 7% neutral
13) It is important to know how a topic relates to the "real world"	85% agree/strongly agree & 13% neutral
16) It is clear to me why I need to study chemistry as part of the degree I chose.	66% agree/strongly agree & 15% neutral in **pre** survey
	85% agree/strongly agree & 3% neutral in **post** survey
8) Sometimes I feel that too much new information is presented in a chemistry lecture	31% agree/strongly agree & 26% neutral in **pre** survey
	51% agree/strongly agree & 34% neutral in **post** survey

23) I find that if too many new terms and concepts are introduced in one lecture, I struggle to understand	61% agree/strongly agree & 21% neutral in **pre** survey 88% agree/strongly agree & 3% neutral in **post** survey
24) I find that if too many new terms and concepts are introduced in one lecture, I lose motivation & interest	47% agree/strongly agree & 23% neutral
28) It is helpful to know in advance what topics each chemistry lecture will be about	82% agree/strongly agree & 17% neutral
29) It is helpful to have had some of the terms explained in advance of a chemistry lecture	89% agree/strongly agree & 8% neutral
14) It is important to know how a new chemistry topic relates to what I already know	85% agree/strongly agree & 13% neutral
36) When studying chemistry, I relate the important information to what I already know instead of just memorising it as it is presented.	59% agree/strongly agree & 31% neutral in **pre** survey 78% agree/strongly agree & 19% neutral in **post** survey
19) It is important to work at chemistry each week instead of only putting a lot of work in close to the final exam	97% agree/strongly agree in **pre** survey 85% agree/strongly agree & 15% neutral in **post** survey
25) A big problem in learning chemistry is being able to memorise all of the information I need to know	66% agree/strongly agree & 24% neutral
33) A lot of the material in chemistry does not make sense to me so I just memorise the information.	52% disagree/strongly disagree & 32% neutral
21) I like to use multimedia tools to help me to study chemistry	60% agree/strongly agree & 24% neutral
18) I like to use textbooks to help me to study chemistry	58% agree/strongly agree & 28% neutral
38) I can access the internet easily when I need to	92% agree/strongly agree & 3% neutral

Table 2: Data extracted from surveys conducted on attitudes to learning chemistry

Attitudes to Context

The first three statements in Table 2 (9, 13 and 16) relate to the applications and relevance of chemistry to a learner's course of study and to the world outside of their lecture room. In the case of all three questions, the students' attitude is that this context is important as the majority of them agreed with the statements. However, there was a difference noted between the pre- and post-module stage for statement 16 which deals with relevance of chemistry to the degree programme the student has chosen. An increase from 66% to 85% participants agreeing that it is clear to them why they need to study chemistry was observed from Semester 1 to Semester 2. As a result of the response to this statement in the pre-module survey, a question related to this statement was added to those being used in the interview phase of this research.

Attitudes to Cognitive Overload

The next three statements (8, 23 and 24) apply to cognitive overload. Students felt that their experience of cognitive overload had increased from the pre- to the post-module stage (from 31% to 51%, statement 8). This is perhaps not surprising as the initial survey was taken at a stage when students who had studied Leaving Cert. chemistry would have been revising familiar material in lectures. The responses to statement 23 show a similar trend and an increase from 61% to 88% was observed.

Attitudes to Pre-Lecture Information and Relationship to Prior Knowledge

The responses to statements 28 and 29 show a strong preference for being provided with information in advance of a lecture (topics that will be dealt with and some chemical terms). Statements 14 and 36 refer to relating a new area of study to prior knowledge and, again, learners demonstrate that they feel this is important to their learning. These responses all support the rationale provided for introducing the online pre-lecture resources (see Chapter 1 and Chapter 2 and Seery & Donnelly, 2011).

Attitudes to Studying Chemistry and Memorisation

Statement 19 deals with adopting a consistent approach to study and working each week. A reduction was observed in the number of learners agreeing that this was the appropriate method from 97% pre- to 85% post-module. This aspect of how students approach their study was followed up in the semi-structured interviews. Statements 25 and 33 relate to whether students resort to memorisation often. 66% of respondents reported that they experienced difficulty with memorising information when learning chemistry which indicates that there are problems being experienced with understanding and with embedding information into long term memory (statement 25). From the responses to statement 33, it seems that 52% of students do not usually resort to memorising information. It is apparent from the responses that this is an area of difficulty for some the students and it was discussed in relation to learner's confidence in their understanding of the main chemistry concepts they came across in the interviews that followed.

Attitudes to Multimedia Tools and Textbooks and Internet Accessibility

The responses to statements 21 and 18 show that roughly equal numbers of these learners like using multimedia tools and textbooks (60% and 58% respectively) to help them to study chemistry. The inclusion of the question on the use of textbooks was suggested by my research collaborator, Dr. Michael Seery, and it is interesting to have found that this student cohort showed a similar level of interest in using both traditional and non-traditional means of learning support. It was important to establish whether the students taking the Introductory Chemistry module felt that they could access the internet easily when they needed to and 92% agreed that they could. As will be discussed later, however, it was apparent from discussions with my research collaborator and with the students interviewed that those who were relying on accessing the internet in college had experienced some difficulties.

Additional Student Comments from Surveys – Some Qualitative Data

Each survey included spaces provided for optional comments. Not many students used this facility and the remarks from the seven who did so are presented below in Table 3. This table also records the name of the degree programme each student belongs to, whether they had studied chemistry at leaving certificate and if the survey was pre- or post-module.

Comments	**Degree Programme**	**Leaving Cert Chemistry**	**Survey Stage**
1 "I really like the online resources we are getting. It is really helpful"	DT 203	Yes	Pre
2 "I cannot link the skills learned in chemistry with my course and my career aims"	DT 222 (repeat student)	No	Pre

3 “Pre-lecture resources are very helpful (additional info and you know what you'll be doing in the next class)”	DT 203	No	Post
4 “Online resources and visual / aural clips are a great way to take a study break from the books.”	DT 299	Yes	Post
5 “I also find working on problems helps my understanding”	DT 222	No	Post
6 “I can access the internet easily at home but in college it's not that easy”	DT 227	No	Post
7 “Finding it quite difficult at the moment to keep up.”	DT 222	No	Post

(DT 203 is the BSc(Forensic & Environmental Analysis), DT 299 is the BSc(Chemical Sciences with Medicinal Chemistry), DT 222 is the BSc(Physics and Physics Technology) and DT 222 is the BSc(Science with Nanotechnology))

Table 3: Remarks made in the optional comment section of the survey on attitudes to learning chemistry.

In two of the remarks (1 and 3) in Table 3, students expressed that they found the online pre-lecture resources helpful. Comment 4 relates to the variety provided by using multimedia tools as an alternative to a textbook. In Comment 6, the respondent indicated that there were difficulties with college internet access. Comment 2 deals with a problem that a student on programme DT 222 (B.Sc. Physics and Physics Technology) is having with identifying the relevance of chemistry to that programme and future career plans. In Comment 5, the student added that working on problems helped their understanding and, in Comment 7, difficulties with keeping up with the subject at that stage (post-Introductory Chemistry module) were reported.

These comments are particularly interesting because each point was also raised at least once during the course of the semi-structured interviews that followed. This methodological triangulation has demonstrated that the case being examined, student experiences of using the pre-lecture resources and of their learning environment for the Introductory Chemistry module, remained the same across the two different methods used and strengthens the validity of the findings arrived at in this work (Cohen & Manion, 1994).

Input from Survey Data Used to Develop Semi-Structured Interview Questions

The analysis performed on the pre-module surveys conducted was used to inform the development of suitable questions for the semi-structured phenomenographic interviews that took place at the beginning of Semester 2. As a result, several survey questions that addressed cognitive overload, context and relevance of chemistry to the student's programme of study were adapted for inclusion in the interview to allow these areas to be probed further.

Qualitative Data – Phenomenographic Interviews with Students

The qualitative phase was the main component of this research and the phenomenographic interviews with nine students that were carried out were designed to attempt to answer the following research questions:

- What are the variations in learners' experiences of using the online pre-lecture resources in their Introductory Chemistry module?
- What are the qualitatively different ways in which students perceive their learning environment for the Introductory Chemistry module?

Each research question will be addressed in turn in the two sections that follow. The findings from this analysis are presented as categories of description and this is followed by a discussion of the structure of the categories within an outcome space which incorporates analysis of these findings with respect to relevant literature.

Learners' Experiences of Using the Online Pre-lecture Resources

The unit of analysis used in this case when examining the interview recordings and transcripts was learners' conceptions of their experience of using the pre-lecture resources. The set of categories presented below in Table 4 that describe the qualitative variation in the ways learners experienced using the pre-lecture resources that was discovered.

Category of Description (least comprehensive first)
1. Task that was supposed to be completed before the lecture
2. Method of assessment that made it easier to pass the module when used
3. Method of assessment that improved understanding in lecture when used
4. Learning tool that improved understanding in the lecture

Table 4: Categories of description for learners' experiences of using the online pre-lecture resources.

The four categories of description formed a nested hierarchy. This means that the second one is viewed as more comprehensive than the first one and so on. In addition, a student whose conception of using the pre-lecture resource is described by category 4 will also be aware of the other three conceptions described by categories 1, 2 and 3. However, it cannot be inferred that a student whose conception is described by category 1 is aware of the other conceptions described by categories 2, 3 and 4.

The analytical framework employed to develop an outcome space based on these categories involved further differentiating experiences into structural and referential dimensions (Marton & Booth 1997). The referential aspect is defined as a particular meaning assigned to the object, in this case the pre-lecture resources, and the structural aspect is "the combination of features discerned and focussed upon by the subject" (Marton & Pong, 2005:336). The resulting outcome space is presented in Table 5 below.

Category of Description (least comprehensive first)	Referential Aspect (meaning assigned)	Structural Aspect
1.Task that was supposed to be completed before the lecture	Task	Focussed on doing the resource as quickly as possible when remembered to and on knowing enough to pass the module.
2.Method of assessment that made it easier to pass the module	Assessment method	Focussed on quiz and on knowing enough to pass the module, not really clear why chemistry is relevant to degree course
3.Method of assessment that improved understanding in the lecture when used	Assessment method and learning tool	Focussed on quiz and passing the module but also seeking to understand concepts, had prior knowledge
4.A learning tool that improved understanding in the lecture	Learning tool	Focussed on understanding, some had prior knowledge and some did not

Table 5: Outcome space for learners' experiences of using the online pre-lecture resources showing referential and structural dimensions.

Each category of description will now be described in some detail and excerpts from the interviews will be provided to support them. As the categories of description that are developed by phenomenographic analysis are based upon a collective consideration of the interview transcripts within a study, it is unusual to find single quotations that completely express each category. The student quotations included were selected because they convey some sense of the category concerned but it is not proposed that they will provide a complete appreciation (Ashwin, 2005).

1. *Task that was supposed to be completed before the lecture*

In this category, the emphasis was on getting the online pre-lecture resources done in the shortest time possible. Students who described this experience usually skipped straight to the quiz component of the resource and worked backwards regardless of whether they thought they knew anything about it. They did not complete some of the resources and did not go back afterwards to look at any they missed. They perceived the resources as tasks that had to be done and were focussed on knowing enough to pass the module.

The focus on completing the resource quickly is illustrated in the excerpt below:

Student H: *A lot of them were multiple choice so obviously some weeks were harder than others so the easier weeks you'd get through in about two minutes and I wouldn't say I ever spent more than five though.*

This student's experience was developed further later in the same interview:

Student H: *I might Google the topic and then try and jog my memory to see if I remembered something I had forgotten to try and get the answer, but that wasn't very often though*

Interviewer: *So would you have Googled something because it wasn't obvious from what was already in the pre-lecture resource?*

Student H: *You see I hadn't really... you know the way there is the notes bit and then the questions? A lot of the time I just skipped straight to the questions because like it would be due on Thursday and I'd be doing it at 11:00 on Wednesday night.*

Apart from providing evidence for this category of description, this information about some students skipping straight to the quiz section of the resource is very useful in relation to the design of the pre-lecture resources and the implications will be dealt with further towards the end of this section.

2. *Method of assessment that made it easier to pass the module*

The qualitative difference between the previous category and this one is that the mark awarded for completing the pre-lecture resources is an important factor here. Students did not complete some of the resources but made more of an effort from resource 3 on when they were told by the lecturer that the quiz marks would go towards their continuous assessment mark. They were focused on passing the module and therefore were prepared to put in sufficient effort to get a good mark on the resource quiz but were not usually interested in going back to find out what the correct answer was when they selected the wrong one. They found that the resources were helpful when they used them and valued them as a way of making it easier to learn about topics that would be on their exam. These students also found that it was not clear to them why they needed to study chemistry as part of their degree. The excerpt below illustrates the preoccupation with assessment that is characteristic of this category. The student has just been asked if they think pre-lecture resources should be introduced for all first year chemistry modules:

Student C: *Yeah, but if people do it though. If it is part of their continuous assessment they probably will do it but if it is not they probably won't.*

3. *Method of assessment that improved understanding in the lecture when used*

In this case, the students' experience of the online pre-lecture resources was that it improved their understanding in the following lecture when they used it but they also emphasised the assessment mark they obtained for the quiz component of the resources. Thus this category differs from the previous one because the resources were perceived to be useful in furthering understanding of chemistry both for and beyond the module exam. Some students completed all of the resources but some did not.

In the excerpt that follows, the student describes the change in approach that resulted after they were told by the lecturer that the quiz marks would go towards their continuous assessment mark from resource 3 on:

Student F: *Yes definitely, you put a bit more effort into them just because you knew it was going towards the final grade.*

In the passage below, a student describes how they experienced using a pre-lecture resource on hybridisation and how this resulted in the following lecture being easy to understand. In this case, the quiz component is not referred to:

Student D: *For example, hybridisation, I had never heard of that before and the pre - lecture resource definitely helped there because I just went through it a few times. At first when I did the pre-lecture resource it didn't really make sense so I just looked through the slides again and it started to make sense. So when I went in I knew exactly what Michael was talking about.*

The students who belonged to this category had already studied chemistry at Leaving Certificate and, in their interviews, they described how this prior knowledge they possessed often had an influence on making them decide to concentrate on the quiz element of the resource for topics that had been covered at second level.

4. *A learning tool that improved understanding in the lecture*

In the final category, students did not emphasise assessment at all, in contrast to categories 2 and 3, but instead were concerned with understanding the subject. Some students in this category had prior knowledge from the Leaving Certificate and some did not. These learners completed all of the pre-lecture resources with the exception of one student who missed one due to a technical problem. All of these students described spending time going through the resource carefully, often reading back over sections several times. In the excerpt below, the student was describing their experience of using the resources and comments on how they could concentrate more easily in a lecture after using one:

Student G: *I thought it was much easier to get into the lecture. I would notice it with other lectures if you go in without knowing anything at all you can lose interest at times, like it is hard to focus unless you actually know... Like if you have that little bit of confidence from what you look at in the pre lecture I think it is easier.*

When asked if there was anything further they wanted to add about their experience of using the resources, this student went on to describe their initial concern over their lack of prior knowledge in chemistry from second level and the way in which the resources alleviated that:

Student G*:* *I suppose it would be just starting out with no chemistry and no physics, so getting into the course at first I was wondering how is this going to work out? Like am I going to be able to do this? But with the pre-lectures I found it much easier, just to get into it.*

A similar comment about the contribution of the resources to their understanding once the first few weeks of the module had gone by was made by another student who had not studied chemistry at Leaving Certificate:

Student I*:* *Yes they came in really handy once I knew what was going on, once I had a little bit of knowledge then it would help me to understand it a bit better.*

The final excerpt selected for this category illustrates that these students approached the resource and the quiz that followed as an opportunity to gain some knowledge on a topic or concept and that, therefore, they did not want to get a right answer to the quiz unless they understood it. The student had just been asked what they usually did if they found that they had given an incorrect answer in the quiz:

Student B: *I find being able to redo the answers is much better because I can understand where I actually went wrong. And if you just went through it and flew through it, say, a, b, c, d, Eeney, Meeney, Miney, Moe, and you did that for the whole lot of them you wouldn't know where you went wrong. Whereas I thought about the answers ... I just continued doing that and then I would actually in the end learn something from it. Whereas rather than flying through it, I would learn absolutely nothing.*

Referential and structural differences between the categories of description

Referential and structural dimensions are used to characterise categories of description. It is recognised that these two aspects, though different, are entwined (Marton and Pong, 2005) and, therefore, they will both be discussed in this section.

The analysis performed to examine the referential dimension of the learner experiences of using the online pre-lecture resources identified three different meanings that students were assigning to them; as tasks, assessments or learning tools. Students in category 3 were assigning two meanings, that of assessment and learning tool, but all others were referring to just one on a regular basis over the course of the interview.

The focus on the task represents the least comprehensive category and these students seemed relatively unprepared for the third level learning environment. The structural dimension of this category shows that they were experiencing difficulties with time management and with identifying what was required of them. In addition, the interaction that these students experienced with the resource was minimal.

The students in category 2 saw the resource as an assessment tool and, within the structural dimension, it was apparent that they did not find that it was clear to them why they needed to study chemistry as part of their degree. This finding seems to indicate that learners who show a lack of intrinsic motivation may not perceive that the particular subject is relevant. Donald (1999) has investigated the differences in performance levels and motivation between students on a physics module who were enrolled either on a Physics or Engineering degree and found that some of the Engineering students changed from being intrinsically to extrinsically motivated over the duration of the course.

Within category 3, there was a perception of the resource as both an assessment method and a learning tool and, thus, from a structural perspective, students were preoccupied with the quiz and on passing the module but they were also seeking to understand concepts. The fact that these students had prior knowledge in the subject at Leaving Certificate level meant that they were influenced by how much they thought they knew about a topic when deciding whether to focus on understanding or not. Therefore, a tactical decision was being made. It is unlikely that had more students been interviewed in this study that someone who did not have prior learning in the subject would have been found to belong to category 3 as there would be no basis for experiencing the resources in two different ways over the course of the module.

Category 4 was the most comprehensive category of description and these learners perceived the resource solely as a learning tool. From a structural perspective, some of these students had studied chemistry at second level and some had not. The categories of description that emerged from this analysis of learner experiences of using pre-lecture resources can be linked to surface (categories 1 and 2), strategic (category 3) and deep (category 4) approaches to learning which are well-documented in the literature and were referred to in the literature review (Martin & Saljo, 1976a and 1976b; Entwistle & Ramsden 1983).

Implications for design of the pre-lecture resources

From the perspective of design of the resources, it is apparent from this work that embedding short questions to be answered within the resource instead of providing the facility to move directly to a quiz task at the end would ensure that learners in categories 1, 2 and 3 would be unable to complete the task without engaging with all of the resource to some extent. There is however also the possibility that some, particularly in category 1, would then opt not to do the resource at all but it would be hoped that their desire to pass the module would ensure they would complete some. This adjustment to the resource format reflects the aligned curriculum model in which the learning environment is constructed so that the teaching methods and assessment tasks are aligned with and support the learning activities that are assumed in the desired learning outcomes (Biggs, 2003). The intent is that students will find that they have no option other than to learn:

> *The learner is in a sense 'trapped', and finds it difficult to escape without learning what he or she is intended to learn.*
>
> (Biggs, 2003:2)

A suggestion that came directly from one of the interview participants was that the quiz questions and answers be randomised so that it would not be possible to keep trying each possible answer until the correct one was reached. It is hoped to adopt this change in the resources for the new academic year also.

Students' Perceptions of their Learning Environment for their Introductory Chemistry Module

The unit of analysis used when examining the interview recordings and transcripts to address the second research question listed at the beginning of this section was students' perceptions of their learning environment for their Introductory Chemistry module (CHEM 1306). In this study, the students' perception of their learning environment is taken to mean the participants' perception of how their introductory chemistry module was presented to them and of what is expected from them in their study of chemistry. The focus is on the qualitative variation in the ways that students experienced the learning environment for introductory chemistry at the higher education institution being studied. Categories of description are formed based on different meanings (or conceptions) students assigned to their learning environment. Categories may be described using two components; how their environment is described and what is focussed on.

The set of categories presented below in Table 6 that describe the qualitative variation in the ways students perceived their learning environment for introductory chemistry that was discovered.

Category of Description (least comprehensive first)
1. Pass the module
2. Practice questions and calculations
3. Gain understanding as basis for rest of degree

Table 6: Categories of description for students' perceptions of their learning environment for their introductory chemistry module, CHEM 1306.

As described for the previous unit of analysis, the three categories of description formed a nested hierarchy. The analytical framework employed to develop an outcome space based on these categories involved further differentiating experiences into structural and referential dimensions (Marton & Booth 1997). The referential aspect is defined as a particular meaning assigned to the object and in this case was best described by the learner motives, and the structural aspect was broken down into what students focussed on when studying and the role of the lecturer. The resulting outcome space is presented in Table 7 below.

Category of Description (least comprehensive first)	**Structural Aspect - What Students Focussed On When Studying**	**Structural Aspect - Role of Lecturer**	**Referential Aspect - Learner Motives**
1.Pass the module	Time management, reading over notes before the exam	Provide clear notes and explain them in the lecture, provide extrinsic motivation (continuous assessment, exam)	Does not want to repeat exam or year
2.Practice questions and calculations	Practicing questions and calculations, reviewing some lecture notes soon afterwards	Ask and answer questions, provide notes and practice questions and extrinsic motivation (continuous assessment, exam)	Wants to perform well in the exam but would also like to understand concepts
3.Gain understanding as basis for rest of degree	Understanding chemistry concepts, working consistently over the semester and following up on areas that cause difficulty in lecture	Ask questions to check understanding, explain concepts, provide learning tools, answer questions	Long term holistic view, wants to understand and gain confidence

Table 7: Outcome space for students' perceptions of their learning environment showing referential and structural dimensions.

Each category of description will now be described in some detail and excerpts from the interviews will be provided to support them.

1. Pass the module

In this category of description, the emphasis was on passing the module and not having to repeat the examination or the year. These students left most of the study they did until just before their mid-semester test and examination, as exemplified in the following passage:

Student H: *Like I literally left everything until the week before and, because the exam was after Christmas, you think you have loads of time and then you leave it until after Christmas and our exam was on the 10th or something. And at Christmas you went, oh I will leave it until after New Year. And then you realise you have like four days and you have to try and cram four subjects into four days. So I probably didn't go about it the right way either.*

There was a lack of clarity about the relevance of chemistry to their degree, either in the first few weeks of the module, or throughout. They focussed on the importance of getting good notes from their lecturer and knowing the information that was necessary to pass the exam but they did not give any prominence to developing an understanding of chemistry concepts. They perceived that their lecturers had an active role in their learning environment but they themselves seemed to adopt a passive approach and this changed only when prompted by extrinsic factors such as their lecturer interacting with them or the assessment requirements. This teacher-centred perception is illustrated in the excerpt below:

Student C: *Like they (the lecturers) go to a lot of effort with the lectures and the fill in the blanks notes and all that. So they are trying to make you have a better understanding by all that. Like they could just give you the notes but then you wouldn't be listening, you might have the chance to not.*

2. Practice questions and calculations

The qualitative difference between the previous category and this one is that these students concentrated a good deal of the studying they do on practicing questions and calculations from tutorial worksheets and from past exam papers. Also, it was clear to them why they needed to study chemistry as part of their degree.

Student F: *In the tutorials or in a few classes before the mid-semester tests, Dr. Seery gave us a set of questions which did help a lot.*

Student D: *... towards the end, I got out the exam papers and made sure that I could do every last one of them.*

These students did not refer to passing or "getting through" the module and want to achieve a good exam performance. Assessments were their main motivators which led to a tactical approach to their learning, as demonstrated in the excerpt below where the student is discussing whether their experience differed if the pre-lecture resource was contributing to the overall assessment mark:

Student D: *Yes because if there was no marking in it, I probably would just... I had the intention of doing them but I probably wouldn't just get around to it.*

They were concerned with developing an understanding of chemistry concepts but they did not always pursue understanding consistently. They sometimes reviewed their lecture notes soon after the lecture and were more likely to do so if they felt they had not understood something. Otherwise, they would wait until an assessment was coming up to review their lecture notes. In the excerpt below, the learner describes how they would follow up on something they found they didn't understand in their lecture:

Student I: *As the class went on it was confusion, just wondering what was going on. The longer it went on, if I didn't start to understand it then I just kind of stopped paying attention. If it was going way over my head, you'd say, I don't know what is going on here so I would sit back and just wait until I could figure it out.*

Interviewer: *So when you say figure it out would you try and do that afterwards?*

Student I: *I'd try and do it at home. I got the book, one of the really big books.*

Interviewer: *Chemistry the Central Science?*

Student I: *That one, so I could just go home and read that on the computer and see if I could figure out from that what it meant.*

The same student then went on to explain what happened in cases where they did not review their notes until close to an assessment:

Student I: *But there was a lot of the time where I felt I knew what was going on but then when I left it after not studying it then when I got home, and then when I left it until the exams I realised that I didn't fully understand it.*

These students would sometimes take an active role and ask a question in a lecture. The role of the lecturer was perceived to be to provide notes and practice questions and to ask and answer questions.

3. Gain understanding as basis for rest of degree

The critical differences between students in this category of description and those in the previous one are that their main motivation was to understand chemistry concepts and they were working consistently over the course of the module. They wanted to gain this understanding so that they would have a good foundation for their degree and thus they had a longer term focus beyond first year, as illustrated in the passage below:

Student B: *I approach the pre-lecture resource as if, whether or not it was part of my exam, I approached it with the idea that it would count for something even if in the short term it didn't count for anything but in the long run it could count for something. How would you explain this? Say we did something this week, we mightn't use it for the next six weeks but on week seven we could use it so approach it as if it is going to count for something in the long run. It is a four year chemistry course basically.*

They took responsibility for their own learning and followed up on areas that caused them difficulty as they arose by consulting a textbook or asking the lecturer or another student about it. In the excerpt below, the student describes how they dealt with a problem in understanding:

Student G: *Yes I looked through the notes, figured it out or if I still can't find anything there, look at a book and again if I still can't find out, go to someone about it.*

Their perception of the role of the lecturer was that they explained concepts, asked questions to check understanding, answered questions and provided learning tools. Thus there was an emphasis on the interaction between them and their lecturer and they perceived a more active role for learners in a lecture. In the excerpt below, the student is responding to a question about what their perception of what their lecturers did during a lecture was:

Student G: *...making sure you understand the concept, even every now and then asking a question to see if people are actually making any sense out of it.*

These students also discussed how their confidence of their knowledge of chemistry had increased over the course of the module:

Student B: *Dr. Seery often times asked, put up your hands if you know the answer and then he'd ask somebody and I was like, yes I knew that answer. So ego boost for me.*

Student E: *Yes because I didn't know what to expect, if it was going to be anything like leaving cert because I didn't feel comfortable with chemistry, it just went out of my head, but I feel much more comfortable now. I think it is kind of set there, the majority of the stuff anyway.*

In the excerpt below, the student is referring to a friend who is studying introductory chemistry in another higher institution who is having difficulty understanding the main concepts:

Student G: *Yes I suppose I would be comfortable enough to actually see about helping her out, like I would be confident that I could possibly give her, if not a whole lot of help, just a little bit.*

Referential and structural differences between the categories of description

The analysis performed to examine the referential dimension of students perceptions of their learning environment identified three different motives that students were assigning when describing their perceptions of their learning environment; (1) to avoid having the repeat their exam, (2) to do well in their exam and, to a lesser extent, to understand and (3) to gain understanding as a basis for their degree. The emphasis on not repeating the exam is a characteristic of the least comprehensive category of description. The structural analysis of this category showed that the students' approach to studying was to leave much of it until just before the assessment and they cited difficulties with managing their time. They also perceived the lecturer to play a very active part in their learning while they only became active as a result of extrinsic motivation (assessments, lecturer interaction). These students were not taking responsibility for their own learning and seemed to be having difficulties with the transition from second to third level. One student in this category described their experience of this change of environment as follows:

Student H: *I was coming from secondary school where everything is handed to you perfectly, you don't have to figure anything out and then to come in here, you are just given sheets and you have to go and find books and you have to get everything organised yourself.*

Category 1 has provided a description of a perception of the learning environment that would appear to encourage a surface approach to learning (Marton and Saljo, 1976a and 1976b) which leads to lower level learning outcomes. These students did not show evidence of taking responsibility for their own learning. Their understanding of what studying involved was reading over their notes and this was only done when motivated by an upcoming assessment. It appears that there may be a lack of metacognitive skills at heart here. Metacognition is often described as “thinking about thinking” and Zimmerman (1995) has characterised it as the evaluation and control by an individual of their cognitive activity and the use of resources available in the task and social environment to attain goals. A lack of metacognitive skills can lead to difficulties with the transition to third level education (Wilson & Gillies, 2005) and a range of initiatives to address this problem have been described in the literature, including learning portfolios (Commander & Valeri-Gold, 2001), reflective learning assignments (Lerner, 2000) and a “learning to learn” programme that was closely linked to the rest of the curriculum (Norton & Crowley, 1995). Entwistle (1987) has argued that when metacognitive skills are applied, students may develop a deeper approach to learning and Chin and Brown (2000) studied learner approaches in a chemistry laboratory at second level and found links between metacognitive activity and approaches to learning. There has been a recent focus on the first year experience at Dublin Institute of Technology (Dublin Institute of Technology, 2009) and it is hoped that a structured approach to developing metacognitive skills among first year undergraduates can be implemented in the near future.

The critical variation between students in category 2 and those in category 1 arises because these learners want to achieve good marks in their assessments. A secondary motive is to understand concepts. The structural dimension of this category revealed that the students’ approach to studying was to practice exam-type questions and to sometimes review lecture notes soon after the lecture. They were more likely to do this if they felt they had not understood something in the lecture. They perceived that the lecturer was taking a very active role in their learning environment and they interacted themselves by asking questions. These learners have a tactical approach to their learning and pursue understanding when they perceive it is necessary for a good performance in an assessment. They have a perception of their learning environment that appears to encourage a strategic approach and they will switch between a surface and deep strategy depending on which one they perceive will provide academic success (Biggs, 1979, Entwistle & Ramsden, 1983). Thus, implementation of a constructively aligned curriculum in which the teaching methods and assessment tasks are aligned with and support the learning activities that are assumed in the desired learning outcomes should ensure that these learners will consistently adopt a deep approach (Biggs, 2003).

The final category of description is the most comprehensive. These learners' main motivation is to understand chemistry concepts and, unlike the previous category, performance in assessments is not the main concern as their focus is longer term. From a structural perspective, their experience of studying was to work consistently and to take action immediately if they did not understand something. Their perception of their lecturer was that they were facilitating their learning and they were active participants, asking and answering questions. These students demonstrated a perception of their learning environment that would seem to encourage a deep approach (Marton and Saljo, 1976a and 1976b) which leads to higher level learning outcomes. In contrast to category 1, these learners appear to have been applying metacognitive skills and to have adjusted to the transition to third level education.

One structural aspect of the learning environment that I would like to discuss further is the students' perception of the role of their lecturer and of the teaching they experienced. Ramsden (1992) describes good teaching as involving giving helpful feedback, making an effort to understand the difficulties students may be having, being good at explanations, making subjects interesting, getting the best out of students, motivating students and showing an interest in what the students have to say. It was clear from the students' perceptions of the lecturers that the learning environment perceived by all students in this case was one in which good teaching was operational. As an example, one student interviewed described an intervention by a lecturer to provide face-to-face formative feedback when they had failed their mid-semester test. As a result, the learner realised what information they needed to include in an answer and they were able to apply this in their examination.

Qualitative Data – Interview with Module Lecturer

The questions used for the interview with the module lecturer are presented in the Appendix.

The data from the lecturer interview was broken down into three main themes once it had been read carefully several times. These were; (1) descriptions that allowed for comparison with student accounts of their experiences, (2) reflections on the design and implementation of the pre-lecture resources and (3) reflections on the learning environment. The analysis of the interviews is presented using these three themes as a way of organising the information.

Descriptions That Allowed for Comparison with Student Accounts of Their Experiences

The interview questions used with the lecturer were adapted from those used with the students and expanded on to include resource design considerations. The similarity in many of the themes discussed meant that there were many opportunities to compare lecturer and student perceptions of the implementation of the pre-lecture resources and of the learning environment in general. The findings are summarised in Table 8.

Correspondence between lecturer account and student accounts
Technical difficulties with access to the resources occurred in the first couple of weeks but the lecturer worked to successfully resolve them and communicated clearly with the students while this was ongoing.
Reference was made to the pre-lecture resource material during the lecture that followed.
During lectures that followed a resource, students were invited to be more active by being asked to answer questions and sometimes contribute to discussions.
Students found that the feedback element of the quiz was very helpful.
The pre-lecture resource allowed learners without prior knowledge on the topic to become familiar with terms and some basic concepts before a lecture and this reduced the cognitive load for them during the lecture.

Being aware of how a concept is applied in the real world (the context) promotes student engagement (*e.g.* fingerprints case study related to London forces).
The transition to third level requires a student to take more responsibility for their own learning.
Students recognised that their lecturer felt the pre-lecture resources were very important to their learning.
Disagreement between lecturer account and student accounts
The lecturer did not think that the continuous assessment mark allocated to completing the resources was an important motivator and wanted to emphasise the benefits to understanding they provided. The students recognised that the resources helped their understanding but several of those interviewed would not have completed the resource if there had been no assessment mark for them.

Table 8: Summary of areas where lecturer and student accounts corresponded and disagreed

The correspondence between the lecturer and student accounts across many areas provides validity for the data on the basis of triangulation. The area where their accounts disagreed, the importance of an assessment mark as a motivator, is based on a lecturer perception of the student experience and thus it does not invalidate the data when this dissonance occurs.

Reflections on the Design and Implementation of the Pre-Lecture Resources

It was evident that the interviewee had reflected considerably on the pre-lecture resources during and after their implementation. The main implications for the design and future implementation for pre-lecture resources were as follows:

- It would be helpful to provide a short induction session in a computer lab to show students how to access the resources and address any technical difficulties.

- As the designer shared an office with colleagues, it was difficult to find a quiet room to record the audio segment of each resource. Availability of a suitable room that could be booked would be very helpful.
- Questions should be integrated throughout the resource so that students interact at each stage and work through it. At present the questions are presented as a quiz section after the information is presented. This change is intended to encourage learners to engage with the resource.

When asked to summarise his advice to someone considering implementing the resources, the lecturer strongly emphasised referring to the resource and what was learned in lectures so that it became an integral element, not an add-on:

> *The number one thing I say, regarding any new resource, is that you have to show the student that you think it is important. So incorporating it into lectures, it is not just a support thing, you have to really, and I am still doing this, but you have to really design your information delivery, if you want to call it that, that is going to be online and in class. That has to be interwoven with a lot of thought, rather than just having your lectures and having something there that's supporting them. That generally doesn't, in my experience, that doesn't work.*

Reflections on the Learning Environment

The interviewee mentioned on several occasions that designing the pre-lecture resources had required taking a step back and analysing each lecture for cognitive load (the number of new terms and concepts). He had found that he was viewing the learning experience from the perspective of the learner and gained fresh insight as a result. The main themes that emerged were as follows:

- The process of designing the pre-lecture resources required that an analysis of cognitive load be performed on each lecture and this resulted in a very illuminating re-evaluation of lectures from the perspective of a novice.

- This reconsideration of the learning environment included evaluating a change to a block teaching model so that learners could focus on one aspect of chemistry at a time. The order in which topics are presented, particularly in the first lectures, is also being examined.
- The breadth and scope of the module remained the same as the core material was unchanged. However, the time spent on discussing relevant case studies at the end of each lecture was reduced.
- The lecturer is re-evaluating these case studies as they may contribute to cognitive load and only ones which reinforce a key concept will be retained.
- The pre-lecture resources allowed for greater interaction in a lecture as questions could be asked on the material introduced there, and, in some cases, a short information retrieval assignment was incorporated into the resource which prompted discussion. The lecturer role was becoming that of learning facilitator rather than knowledge provider.
- It was considered that a concept dealt with in a previous lecture in the module could not really be considered prior knowledge and was perhaps more accurately described as concurrent knowledge.

Thus, implementation of the pre-lecture resources also significantly changed how the lecturer approached his teaching and has substantially increased his awareness of the perspective of a novice chemistry learner. Redesign of the first year learning experience in chemistry in this light is ongoing.

Conclusion

This study examining student experiences of using online pre-lecture resources and of their learning environment in an introductory chemistry module has addressed the three research questions posed by means of mixed methods, which were comprised of an attitudes survey and semi-structured phenomenographic interviews. The conclusions from the quantitative and qualitative phases of the research will be examined in turn and will then be considered holistically.

Conclusions from Quantitative Analysis

The quantitative phase of the study provided data on attitudes towards a number of aspects of the learning environment across the entire student cohort. Among the pertinent results was the finding that these learners had a strong preference for being provided with information in advance of a lecture as this supports the rationale for introducing the pre-lecture resources. The pre-module survey indicated that about one third of respondents did not see why the study of chemistry was relevant to their degree and, as a consequence, this was investigated in the interviews that followed. A piece of information available from the survey that was not investigated in the interviews was that roughly equal numbers of these students liked using multimedia tools (60%) as liked using a textbook (58%) to help them to study chemistry. This provides a snapshot of learner preferences in this regard. Seven respondents in total provided additional comments on the surveys and each point made was also raised at least once in the interviews. This observation provides methodological triangulation for the research findings and strengthens their validity.

Conclusions from Qualitative Analysis

A description of the qualitatively different ways in which learners experienced using the pre-lecture resources emerged on analysis of the interview transcripts and four categories of description resulted. These categories could be related to a particular approach to learning; surface, strategic or deep. From the perspective of ensuring that the intended learning outcomes are met, the design of the assessment component of the resource could be changed to encourage strategic learners to opt for a deep approach and surface learners may need some support with developing metacognitive skills before they can change their approach.

A description of the qualitatively different ways in which the students experienced their learning environment for their Introductory Chemistry module was also discovered on analysis of the transcripts. Three categories of description emerged and each could be related to a particular approach to learning. The investigation of student perceptions of relevance of chemistry to their degree that was prompted by the quantitative phase of the research showed that this contributed to a perception that led to a surface approach to learning. To ensure that the intended module learning outcomes are met, ensuring strategic alignment of learning outcomes, assessments and learning activities and teaching methods should encourage strategic learners to opt for a deep approach and, as stated previously, surface learners may need some support with developing metacognitive skills before they can change their approach.

The interview with the lecturer who implemented the resources allowed the third research question to be addressed. It was found that the lecturer's perception of the resources and the learning environment was consistent with those of the learners but there was one important exception; the lecturer underestimated the importance to students of assigning a continuous assessment mark to the resources. This finding has been communicated to the lecturer so that he is aware of the influence that assessment has on the resources. In addition, some important reflections on implications for the future implementation of the resources and on the learning environment for this module in general were captured as a result of the interview.

Recommendations

An outcome of this study was that issues in relation to transition to third level education and the development of metacognitive skills became apparent among one category of students that was identified in the qualitative analysis. It is recommended that the implementation of strategies to address this be examined, both within the module and across the suite of modules in semester one. An aspect of this is an understanding of why studying chemistry is relevant to a particular degree and this has been identified as an issue for some learners in this study. It is also recommended that the change proposed by the lecturer to embed the assessment questions throughout each resource be implemented as it will mean that learners cannot opt to skip the slides and go straight to the assessment quiz. The proposal by one of the interview participants that the answers to the questions be randomised should also be considered.

Reflections

This study has provided important findings in relation to student experiences of an intervention designed to reduce their cognitive load. It is apparent that the pre-lecture resources are reducing cognitive load very effectively for some learners but two main areas to be addressed have been identified to ensure that this benefit is maximised by taking account of the range of student experiences. They are the development of metacognitive skills and integration of the assessment questions into the resource.

Based on the success of this pilot implementation of online pre-lecture resources in a first year chemistry module, I plan to develop similar resources for difficult topics within my own teaching in semester two of first year. Other future work will be the consideration of explicitly incorporating tasks to develop metacognitive skills into the Introductory Chemistry module that was the focus of this study.

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Appendices

1. Information sheet prepared about the research for participants
2. Consent form provided to participants
3. Survey
4. Student interview questions used
5. Lecturer interview questions used
6. Detailed survey results

Appendix 1. Information sheet prepared about the research for participants

Information Sheet

Project Title: A collaborative Approach to Investigating SCOPE (Scaffolding for Cognitive Overload using Pre-lecture E-resources) for undergraduate chemistry students

- This research is being undertaken for a part-time Masters in Higher Education (Claire Mc Donnell) and a part-time Masters in Applied eLearning (Michael Seery).
- The overall objective of this project is to probe students' perception of the web-based pre-lecture resources implemented in relation to their learning and their attitudes towards chemistry.

- The two main aspects of the project are;
    1. To carry out surveys on students on their attitudes about learning chemistry
    2. A number of students may be invited to be part of a focus group and / or be interviewed at a later date based on the initial findings.

- The surveys taken and interviews carried out are completely confidential and it will be ensured that the information provided in the final report is made anonymous and will not allow the identification of any participant.

All participants are required to read this information sheet and complete the consent form that follows.

Thank you for your cooperation. Please check the School website for the report on our findings next summer;
http://www.dit.ie/colleges/collegeofsciencesandhealth/chemistry/ .

Claire Mc Donnell and Michael Seery

Appendix 2. Consent form provided to participants

CONSENT FORM

Researcher's Name: **Claire Mc Donnell** (use block capitals)	**Title:** Dr
Faculty/School/Department**:** **School of Chemical and Pharmaceutical Sciences**	
Title of Study**:** **Scaffolding for Cognitive Overload using Prelecture E-resources (SCOPE)**	
To be completed by the: Participant	

Do you agree to the following statements: ***(Please indicate below by circling the appropriate response)***

3.1 You have been fully informed or read the information sheet about this study.

3.2 You have had an opportunity to ask questions and discuss this study.

3.3 You have received satisfactory answers to all of your questions.

3.4 You have received enough information about this study

3.5 You understand that you are free to withdraw from this study

- at any time
- without giving a reason for withdrawing
- without affecting your future relationship with the college

3.6 You agree to take part in this study the results of which are likely to be published.

3.7 You have been informed that this consent form shall be kept in the confidence of the researcher.

YES NO

Signed____ Date ____________________

Name in Block Letters ____

Signature of Researcher ____________________________________ Date ____________________

Appendix 3. Survey

Survey of DIT First Year Chemistry Students On Learning Chemistry 2010-11

I am a lecturer at Dublin Institute of Technology, Kevin Street, Dublin 8 and am undertaking research for a part-time Masters in Higher Education. This survey is completely confidential and will be made anonymous. Please answer all questions honestly and to the best of your ability

Course Code: DT 203 ☐ DT 222 ☐ DT 227 ☐ DT 299 ☐

Q1 Have you signed the consent form?

Yes ☐ **No** ☐

Q2 Have you studied chemistry before at second level or for another third level course?

Yes ☐ **No** ☐

Q3 Please put a tick beside the subjects you studied for your Leaving Cert / A level.

Biology ☐

Chemistry ☐

Physics ☐

Physics and Chemistry combined ☐

- A number of statements are now presented which may or may not reflect your views about learning chemistry and your experience of this to date
- Please tick the box which best reflects your opinion / feeling about the statements.
- If you don't understand a statement, leave it blank.
- If you have no strong opinion, choose neutral

What are your opinions about learning chemistry to date?

Please tick ONE box on each line to show your opinions.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
4) I am enjoying chemistry					
5) I feel I am coping well with chemistry so far					
6) I have found chemistry easy so far					
7) Having studied chemistry at second level makes it easier to learn at college					
8) Sometimes I feel that too much new information is presented in a chemistry lecture					
9) It is important to know why I need to learn about a topic.					
10) I am getting worse at chemistry					
11) I understand what we have done so far in chemistry lectures					
12) Chemistry is definitely "my" subject					
13) It is important to know how a topic relates to the "real world"					
14) It is important to know how a new chemistry topic relates to what I already know					
15) I want to do as well as I can in chemistry					
16) It is clear to me why I need to study chemistry as part of the degree I chose.					
17) I find that a textbook is useful when I am studying chemistry					
18) I like to use textbooks to help me to study chemistry					
19) It is important to work at chemistry each week instead of only putting a lot of work in close to the final exam					
20) Sometimes I find I learn more about a subject by discussing it with other students than I do by sitting and revising at home					
21) I like to use multimedia tools* to help me to study chemistry					
22) Chemistry is made up of many disconnected topics					

* Multimedia tools present information using a combination of images, sound, audio and text. Examples are interactive online resources including animations, online quizzes, video clips, audio clips and powerpoint presentations.

Optional comment:____

Please tick ONE box on each line to show your opinions.

	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
23) I find that if too many new terms and concepts are introduced in one lecture, I struggle to understand					
24) I find that if too many new terms and concepts are introduced in one lecture, I lose motivation and interest					
25) A big problem in learning chemistry is being able to memorise all of the information I need to know					
26) I think about the chemistry I experience in everyday life					
27) My friends and family think that chemistry is a difficult subject					
28) It is helpful to know in advance what topics each chemistry lecture will be about					
29) It is helpful to have had some of the terms explained in advance of a chemistry lecture					
30) When I have studied a topic in chemistry and I feel I understand it, I still have difficulty answering questions and problems on that topic					
31) Nearly everyone can understand chemistry if they work at it.					
32) We use this statement to discard the survey when someone is not reading the questions. Please select agree (not strongly agree) for the response to this statement.					
33) A lot of the material in chemistry does not make sense to me so I just memorise the information.					
34) If I get stuck on a chemistry question on my first attempt, I usually try to figure out a different way that works.					
35) The skills I use to understand chemistry can be helpful to me in my everyday life					
36) When studying chemistry, I relate the important information to what I already know instead of just memorising it as it is presented.					
37) When I am answering chemistry questions and problems, I often do not really understand what I'm doing					
38) I can access the internet easily when I need to					

Optional comment:____

Appendix 4. Student interview questions used

Questions and Opening Statement Used for Interviews with Students

Opening statement (modified from Ireland, Joseph, Tambyah, Mallihai M., Neofa, Zui, & Harding, Terry (2009) *The tale of four researchers : trials and triumphs from the phenomenographic research specialization.* In: AARE 2008 International Education Conference : Changing Climates : Education for Sustainable Futures, 30th November - 4th December2008, Queensland University of Technology, Brisbane, http://www.aare.edu.au/08pap/ire08373.pdf.)

I am doing a study to find out how students experienced using online pre-lecture resources for the chemistry module CHEM 1306 in Semester 1. There are no wrong answers as I am interested in exploring your experiences and ideas. I'd like you to feel that ***I*** *am the learner here and* ***you*** *the expert on your particular experiences with the online resources. I will try to be like a blank slate – I will ask some questions but I would like you to do most of the talking and I'll do the listening. If you need to take some time to think before you answer, that's no problem.*

As the study is on an anonymous and confidential basis, I won't mention your name while the conversation is being recorded.

Openers (5 mins max)

1. What science subjects did you study for your Leaving Certificate?
2. Can you access the internet at college - and at home?
3. Did you have any technical difficulties with accessing the online pre-lecture resources and using them?
4. If so, did it take long to get these difficulties sorted out?
5. Do you like to use online / multimedia* tools when you are studying chemistry?

If so, can you describe why that is and give an example of how you would typically use multimedia tools in this way.

(*Multimedia tools present information using a combination of images, sound, audio and text. Examples are interactive online resources including animations, online quizzes, video clips, audio clips and powerpoint presentations.)

Experiences of Using Pre-lecture Resources (15-20 mins approx)

6. Can you **describe what you typically did** in advance of, during and after a chemistry lecture for Module CHEM 1306 in Semester 1 when;

a) a prelecture resource was provided (value of feedback? Learning by making mistakes in quiz) and
b) when one was not available.
(a list of pre-lecture resource topics is provided)

7. Did your approach to the lectures vary sometimes? (Can you give some examples of when this happened and the reasons why?)
8. Did you experience any differences during a chemistry lecture for which you had used a pre-lecture resource and one for which you didn't?
9. Was your experience any different when the pre-lecture resource quizzes were included in your assessment mark, after lecture 3?
10. Describe your most positive experience with the pre-lecture resources.
11. Describe your most negative experience with the pre-lecture resources.
12. What impact, if any, have the pre-lecture resources had on your experience of learning chemistry?
13. Now that you have completed module CHEM 1306, do you feel confident that you have a good understanding of the main concepts that you learned about? (What are the reasons for your answer)
14. Looking back at semester one, is there anything that you would now do differently in your approach to module CHEM 1306?
15. Is there anything that you recommend that would improve the pre-lecture resources?
16. Should pre-lecture resources be introduced for all chemistry modules in first year?

Cognitive Load / Context (10 mins approx)

17. Is it helpful to know in advance what topics a chemistry lecture will be about? (Can you give an example)
18. Is it helpful to have some of the terms explained in advance of a chemistry lecture? (Can you give an example)

19. Do you ever think that there is too much information being presented in a chemistry lecture? If so, how often does this happen?

20. If yes to the previous question - Can you describe your experience in a lecture where this happens.

21. If yes to Q 19 - Did using the pre-lecture resources for a lecture have any link to whether you felt that too much information was being presented in a chemistry lecture?

22. Is it important to know how a new chemistry topic relates to what you already know? (why, can you describe an example)

23. Is it important to know how a chemistry topic relates to the real world? (Why? can you describe an example?)

24. Is it clear to you why you need to study chemistry as part of the degree you chose? (give an example)

Perceptions of the Learning Environment (10 mins approx)

25. In your opinion, for module CHEM 1306, what was the most important consideration for gaining an understanding of the chemistry concepts involved?

26. What do you think your module CHEM 1306 lecturers consider to be the most important factor in gaining an understanding of the chemistry concepts involved?

27. In your opinion, what was the most important consideration for passing the end of semester exam when studying chemistry for module CHEM 1306?

28. Describe how you view the role of your chemistry lecturers for module CHEM 1306.

29. Describe what you think **should** be the role of the chemistry lecturer.

30. Which aspects of the teaching for module CHEM 1306 did you find to be the most helpful?)

31. (Which aspects of the teaching for module CHEM 1306 did you find to be the most unhelpful?)

32. Is there any way, in your opinion, that your chemistry module CHEM 1306 could be improved?

33. Is there anything else you would like to say about your experience of using the pre-lecture resources for module CHEM 1306 or your experience of being a student on that chemistry module that has not been discussed so far?

TOPICS DEALT WITH IN EACH PRELECTURE RESOURCE (PL)

PL 1 – Atoms and elements

PL 2 - Atomic orbitals and electronic configurations

PL 3 - Determining number of valence electrons from electronic configurations and grouping elements in the periodic table

PL 4- Types of bonding and electronegativity

PL 5- Intermolecular attractive forces (Van der waals interactions and ionic interactions)

PL 6 – Valence shell electron pair repulsion theory

PL 7 – Molecular orbital theory and hybridisation

No prelecture resources for nanoscience lectures

PL 13 Introduction to thermodynamics and first law

PL 14 Enthalpy and description of thermochemical equations

Appendix 5. Lecturer interview questions used

Draft Questions for Lecturer Interview – March 2011

Opening statement (modified from Ireland, Joseph, Tambyah, Mallihai M., Neofa, Zui, & Harding, Terry (2009) *The tale of four researchers : trials and triumphs from the phenomenographic research specialization.* In: AARE 2008 International Education Conference : Changing Climates : Education for Sustainable Futures, 30th November - 4th December2008, Queensland University of Technology, Brisbane, http://www.aare.edu.au/08pap/ire08373.pdf.)

I am doing a study to find out how the lecturer concerned experienced designing and implementing online pre-lecture resources for the chemistry module CHEM 1306 in Semester 1. There are no wrong answers as I am interested in exploring your experiences and ideas. ***I*** *am the learner here and* ***you*** *the expert on your particular experiences with the online resources. I will try to be like a blank slate – I will ask some questions but I would like you to do most of the talking and I'll do the listening. If you need to take some time to think before you answer, please do so.*

As the study is on an anonymous and confidential basis, I won't mention your name while the conversation is being recorded.

Openers (5 mins max)

1. Were you aware of any technical difficulties that arose for students accessing the online pre-lecture resources and using them?

2. If so, did it take long to get these difficulties sorted out and will you change your approach in any way next year?

Experiences of Using Pre-lecture Resources (25 mins approx)

3. Can you **describe what you typically did** in advance of, during and after a chemistry lecture for Module CHEM 1306 in Semester 1 when;

a) you had provided a prelecture resource and

b) when you hadn't.

(Prompt with list of pre-lecture resource topics)

4. Did your approach to the lectures vary over the semester? (Can you give some examples of when this happened and the reasons why?)

5. Did you experience any differences during a chemistry lecture for which you had used a pre-lecture resource and one for which you didn't?
6. Were you aware of any difference in the student's approach when the pre-lecture resource quizzes were included in their assessment mark, after lecture 3?
7. Describe your most positive experience with the pre-lecture resources.
8. Describe your most negative experience with the pre-lecture resources.
9. What impact, if any, have the pre-lecture resources had on your experience of teaching chemistry on this module?
10. Now that module CHEM 1306 is complete, do you feel confident that the student cohort has a good understanding of the main concepts that you taught? (What are the reasons for your answer)
11. Looking back at semester one, is there anything that you would now do differently in your approach to teaching module CHEM 1306?
12. Is there anything that you think would improve the pre-lecture resources? (Will you be making those changes?)
13. Should pre-lecture resources be introduced for all chemistry modules in first year?

Cognitive Load / Context (20 mins approx)

14. What approach is required to restructure a chemistry module to optimise consideration of the working memory model?
15. Would the changes required reduce the breadth / scope of the module syllabus?
16. Do you think it is helpful to students to know in advance what topics a chemistry lecture will be about? (Can you give an example)
17. Do you think it is helpful to students to have some of the terms explained in advance of a chemistry lecture? (Can you give an example)
18. Do you ever think that there is too much information being presented in a chemistry lecture? If so, how often does this happen?
19. If yes to previous question - Can you describe your experience in a lecture where this happens.

20. If yes to Q 18 - Did providing the pre-lecture resources for a lecture have any link to whether you felt that too much information was being presented in a chemistry lecture?

21. Do you think it is important for a student to know how a new chemistry topic relates to what they already know? (why, can you describe an example)

22. Do you think it is important for a student to know how a chemistry topic relates to the real world? (Why, can you describe an example)

23. Do you think it is clear to the student cohort why they need to study chemistry as part of the degree they chose? (give an example)

Perceptions of the Learning Environment (20 mins approx)

24. In your opinion, for module CHEM 1306, what was the most important factor for students to gain an understanding of the chemistry concepts involved?

25. What do you think the students on module CHEM 1306 consider to be the most important factor in gaining an understanding of the chemistry concepts involved?

26. In your opinion, what was the most important consideration for passing the end of semester exam when students were studying chemistry for module CHEM 1306?

27. Do you think the pre-lecture resources were linked in any way to students' attitude to their subject and their motivation and engagement levels? (give an example)

28. Describe how you view your role as a chemistry lecturer for module CHEM 1306.

29. Describe how you think the students view the role of a chemistry lecturer for module CHEM 1306

30. Describe what you think **should** be the role of the chemistry lecturer.

31. What do you think good teaching involves? (Can you give me an example of good teaching? Why are particular aspects important?)

32. Is there any way, in your opinion, that chemistry module CHEM 1306 could be improved?

33. Is there anything else you would like to say about your experience of implementing the pre-lecture resources for module CHEM 1306 or your experience of being a lecturer on that chemistry module that has not been discussed so far?

Perceptions and Reflections on Collaborative Research Approach (10 mins approx)

34. Describe your experience of undertaking a collaborative research approach to the work undertaken on the pre-lecture resources.
35. How does this experience compare to previous individual education research projects?
36. Describe your most positive experience in relation to the collaborative research approach.
37. Describe your most negative experience in relation to the collaborative research approach.
38. What is your perception of the experience that the other research collaborator had? What evidence do you have for the experience you think they had?
39. Is there anything that, with hindsight, you would now do differently in relation to your approach to working collaboratively on this research project?
40. Do you anticipate using this approach again on future education research projects? (Why?)
41. What recommendations and guidance would you give to other researchers considering using a collaborative approach?

Appendix 6 – Detailed Survey Results

(SA = strongly agree, A = agree, N = neutral, D = disagree, SD = strongly disagree, B= blank)

DT 203 = BSc(Forensic and Environmental Chemistry)

DT 227 =BSc(Science with Nanotechnology)

Dt 299 = BSc(Chemical Sciences with Medicinal Chemistry)

DT 222 = BSc(Physics Technology)

Course & Prior Chem		LC Biology	LC Physics	LC Phys/Chem	Q4 SA	A	N	D	SD	Q5 SA	A	N	D	SD	Q6 SA	A	N	D	SD	B	Q7 SA	A	N	D	SD	B
DT 203 Pre (LC Chem)	11	13	3	1	1	8	2			1	7	3			1	4	6				4	6		1		
DT 203 Pre (No Chem)	7					2	4		1		3	2		2			3	2	1	1			3			4
DT 203 Post (LC Chem)	9	12	2	2		6	1	1			4	5					5	4			2	5	2			
DT 203 Post (No Chem)	7					4	3				3	2	2				3	1	3		1	2	2			2
DT 227 pre (LC Chem)	5	8	3	0		4	1			1	3		1			3		1	1		3	1	1			
DT227 pre (No Chem)	4					3	1				1	2	1				1	3				2				2
DT 227 post (LC Chem)	3	6	2	0		3					3					3					1	2				
DT 227 post (No Chem)	4					3	1				3			1			1	3				1	1		1	1
DT 299 post (LC Chem)*	2	2	0	0	2					1	1				1	1					2					
DT 299 post (No Chem)*	0																									
DT222 pre (LC Chem)	3	1	6	0		2	1				2			1		2			1		1	1				1
DT222 pre (No Chem)	5				1	2	2				4			1		2	1	1		1			3		1	1
DT222 (3) AND DT 227 (1) pre (repeats)	4	1	4	0	3		1				2		2		1		1	1	1		1		3			
DT 222 post (LC Chem)	2	0	6	0		2					2					1	1				1		1			
DT 222 post (No Chem)	5					2	2	1			2	1		2			2		2	1			3			2
Overall Total	71	43	26	3	7	41	19	2	1	3	40	15	6	7	3	16	24	16	9	3	16	20	19	1	2	13
Pre total	39	23	16	1	5	21	12	0	1	2	22	7	4	4	2	11	12	8	4	2	9	10	10	1	1	8
Post total	32	20	10	2	2	20	7	2	0	1	18	8	2	3	1	5	12	8	5	1	7	10	9	0	1	5
Overall percent	50 (with LC chem)	61	37	4	10	58	27	3	1	4	56	21	8	10	4	23	34	23	13	4	23	28	27	1	3	18
Pre percent	49 (LC Chem)	59	41	3	13	54	31	0	3	5	56	18	10	10	5	28	31	21	10	5	23	26	26	3	3	21
Post percent	50 (LC Chem)	62	31	6	6	63	22	6	0	3	56	25	6	9	3	16	38	25	16	3	22	31	28	0	3	16

Course & Prior Chem	Q8 SA	A	N	D	B	SD	Q9 SA	A	N	D	SD	B	Q10 SA	A	N	D	SD	B	Q11 SA	A	N	D	SD	B	Q12 SA	A	N	D	SD
DT 203 Pre (Chem)		1	2	6		2	5	5	1						2	5	4		2	8	1						7	4	
DT 203 Pre (No Chem)	1	2	1	3			3	3				1			3	1	1	2		2	4		1				3	2	2
DT 203 Post (Chem)	1	3	4			1	2	5	2					1		7	1			6	3						3	5	1
DT 203 Post (No Chem)	1	4	1	1			4	3								6	1			5	1	1				1	3	2	1
DT227 pre (Chem)		1	2	1	1		2	2		1						4	1		1	4							3	1	1
DT227 pre (No Chem)	3		1				1	3							1	3					4						2	2	
DT 227 post (Chem)		1	1	1			1	2								2	1		1	2						1	2		
DT 227 post (No Chem)		3	1					2	1		1				1	1	2			2	1	1					3		1
DT 299 post (Chem)			1	1				1	1							1	1		1	1					1	1			
DT 299 post (No Chem)																													
DT222 pre (Chem)	1		1	1			1	2							1	2				2		1					2	1	
DT222 pre (No Chem)			3		1	1	3	1				1				3	1	1	2	2				1	1	1	1	1	1
DT222 (3) AND DT 227 (1) pre (repeats)	2	1		1			1	3							2	1	1			3	1						1	1	2
DT 222 post (Chem)			1	1			1	1								1	1			2							1	1	
DT 222 post (No Chem)	2	1	2				2	3							4		1			3		1	1				1	1	3
Overall Total	11	17	21	16	2	4	26	36	5	1	1	2	0	1	14	37	16	3	7	42	15	4	2	1	2	4	32	21	12
Pre total	7	5	10	12	2	3	16	19	1	1	0	2	0	0	9	19	8	3	5	21	10	1	1	1	1	1	19	12	6
Post total	4	12	11	4	0	1	10	17	4	0	1	0	0	1	5	18	8	0	2	21	5	3	1	0	1	3	13	9	6
Overall percent	15	24	30	23	3	6	37	51	7	1	1	3	0	1	20	52	23	4	10	59	21	6	3	1	3	6	45	30	17
Pre percent	18	13	26	31	5	8	41	49	3	3	0	5	0	0	23	49	21	8	13	54	26	3	3	3	3	3	49	31	15
Post percent	13	38	34	13	0	3	31	53	13	0	3	0	0	3	16	56	25	0	6	66	16	9	3	0	3	9	41	28	19

Course & Prior Chem	Q13 SA	A	N	D	SD	Q14 SA	A	N	D	SD	B	Q15 SA	A	N	D	SD	Q16 SA	A	N	D	SD	Q17 SA	A	N	D	SD	Q18 SA	A	N	D	SD	B
DT 203 Pre (Chem)	3	7	1			3	6	2				8	3				7	3	1			3	4	4			2	5	4			
DT 203 Pre (No Chem)	3	3		1		2	3	2				4	2		1		2	4	1			2	3	2			1	5	1			
DT 203 Post (Chem)	3	6				1	6	2				3	5	1			4	5				1	6	1	1		1	5	1	2		
DT 203 Post (No Chem)	4	2	1			4	2	1				7					4	3				1	4	1	1			5	1	1		
DT227 pre (Chem)	3	2				3	2					4		1			4		1			2	1		2		1	2			2	
DT227 pre (No Chem)		4					4					3	1				1	1	1	1		1	1	2			1	1	1			1
DT 227 post (Chem)	1	2				1	2					2	1				1	2				1		2			1		1	1		
DT 227 post (No Chem)		2	1		1		2	1	1			3	1				2	1	1				2	1		1		2	1		1	
DT 299 post (Chem)		2					1	1				2					2							2					2			
DT 299 post (No Chem)																																
DT222 pre (Chem)	1	2				1	2					2	1				1	1	1				1	2				1	2			
DT222 pre (No Chem)	2	2	1			2	2				1	4						1	1	1	2	1	1	3			1	2	2			
DT222 (3) AND DT 227 (1) pre (repeats)	2	2				2	2					4						1		1	2			3	1			1	3			
DT 222 post (Chem)	1		1				2					1	1					1		1			2					5				
DT 222 post (No Chem)	3	2				3	2					4	1					2		2	1	2		1	2		2		1	1		1
Overall Total	26	38	5	1	1	22	38	9	1	0	1	51	16	2	1	0	28	25	7	6	5	14	25	24	7	1	10	31	20	5	3	2
Pre total	14	22	2	1	0	13	21	4	0	0	1	29	7	1	1	0	15	11	6	3	4	9	11	16	3	0	6	17	13	0	2	1
Post total	12	16	3	0	1	9	17	5	1	0	0	22	9	1	0	0	13	14	1	3	1	5	14	8	4	1	4	14	7	5	1	1
Overall percent	37	54	7	1	1	31	54	13	1	0	1	72	23	3	1	0	39	35	10	8	7	20	35	34	10	1	14	44	28	7	4	3
Pre percent	36	56	5	3	0	33	54	10	0	0	3	74	18	3	3	0	38	28	15	8	10	23	28	41	8	0	15	44	33	0	5	3
Post percent	38	50	9	0	3	28	53	16	3	0	0	69	28	3	0	0	41	44	3	9	3	16	44	25	13	3	13	44	22	16	3	3

Course & Prior Chem	Q19 SA	A	N	D	SD	Q20 SA	A	N	D	SD	Q21 SA	A	N	D	SD	B	Q22 SA	A	N	D	SD	B	Q23 SA	A	N	D	SD	Q24 SA	A	N	D	SD	B
DT 203 Pre (Chem)	6	5				2	6	1	1	1	2	4	5						5	6				6	4	1		1	5	2	3		
DT 203 Pre (No Chem)	2	5				2	2	2	1		1	4		2				1	4	2			2	3	2			2		3	2		
DT 203 Post (Chem)	3	5	1			1	3	4	1			5	2	2				2	7					7	1	1			7	1	1		
DT 203 Post (No Chem)	3	3	1			1	5		1		3	1		2	1				4	3			3	4				2	2	3			
DT227 pre (Chem)	4	1				3	1	1			3	2							1	2	2			2	1	2		1		2	2		
DT227 pre (No Chem)	1	2			1	1	2		1		2		1		1				3	1				4					2		2		
DT 227 post (Chem)	2		1			1		2			1	1	1							2	1		1	1		1				1	2		
DT 227 post (No Chem)	1	2	1			1	1	2				2	1		1					2	1	1		3		1		1	1		2		
DT 299 post (Chem)		2							2		1	1								1	1			2					1	1			
DT 299 post (No Chem)																																	
DT222 pre (Chem)	1	2					3				1	1	1						1	2			1		1	1		1	1		1		
DT222 pre (No Chem)	2	3				3	2				1	3	1						2	1	1	1	2			3				1	3		1
DT2 22 (3) AND DT 227 (1) pre (repeats)	2	2				1	3					2	2					2	1	1			1	3				1	3				
DT 222 post (Chem)		1	1			1	1						1		1					2				2					1		1		
DT 222 post (No Chem)	3	2				2	2	1				2	2			1			3	1		1	3	2					1	2	2		
Overall Total	30	35	5	0	1	19	31	13	7	1	15	28	17	6	4	1	0	5	31	26	6	3	13	39	9	10	0	9	24	16	21	0	1
Pre total	18	20	0	0	1	12	19	4	3	1	10	16	10	2	1	0	0	3	17	15	3	1	6	18	8	7	0	6	11	8	13	0	1
Post total	12	15	5	0	0	7	12	9	4	0	5	12	7	4	3	1	0	2	14	11	3	2	7	21	1	3	0	3	13	8	8	0	0
Overall percent	42	49	7	0	1	27	44	18	10	1	21	39	24	8	6	1	0	7	44	37	8	4	18	55	13	14	0	13	34	23	30	0	1
Pre percent	46	51	0	0	3	31	49	10	8	3	26	41	26	5	3	0	0	8	44	38	8	3	15	46	21	18	0	15	28	21	33	0	3
Post percent	38	47	16	0	0	22	38	28	13	0	16	38	22	13	9	3	0	6	44	34	9	6	22	66	3	9	0	9	41	25	25	0	0

Course & Prior Chem	Q25					Q26					Q27						Q28					Q29					Q30					
	SA	A	N	D	SD	SA	A	N	D	SD	SA	A	N	D	SD	B	SA	A	N	D	SD	SA	A	N	D	SD	SA	A	N	D	SD	B
DT 203 Pre (Chem)		6	3	2		1	5	3	2		3	5	1	1	1		2	7	2			2	6	2	1		3	4	3	1		
DT 203 Pre (No Chem)	1	4	2					3	3	1	1	5	1				3	4				3	4				2	1	4			
DT 203 Post (Chem)	3	3	3				2	3	4		2	7					2	3	4			2	5	2			2	5	1	1		
DT 203 Post (No Chem)	1	1	3	2			1		4	2	2	4	1				2	4	1			3	4					6	1			
DT227 pre (Chem)	1	3	1				3	1		1		3	2				2	3				1	4					2	3			
DT227 pre (No Chem)	1	3						1	3		1	3					2	9				2	2					3		1		
DT 227 post (Chem)		2		1			2	1				2	1				1	1	1			2		1				1	2			
DT 227 post (No Chem)	1	3						1	3		1	1	1	1				3		1		1	2		1			3	1			
DT 299 post (Chem)		2				1	1				1	1					2					2					1	1				
DT 299 post (No Chem)																																
DT222 pre (Chem)	1	1		1			1	1		1		1	2				1		2			1	1	1				1	2			
DT222 pre (No Chem)	1	2	1				2		2	1	1	1	2			1	2	2	1			3	2					2	1	1		1
DT222 (3) AND DT 227 (1) pre (repeats)	1	1	2				2	1	1		2	2					2	2				2	2				1	2	1			
DT222 post (Chem)		1	1					1		1		2					1	1					2					1	1			
DT 222 post (No Chem)	1	3	1				1	3	1		1	2	2				2	2	1			3	2					2		2		1
Overall Total	12	35	17	6	0	2	20	19	23	7	15	39	13	2	1	1	24	34	12	1	0	27	36	6	2	0	9	34	20	6	0	2
Pre total	6	20	9	3	0	1	13	10	11	4	8	20	8	1	1	1	14	20	5	0	0	14	21	3	1	0	6	15	14	3	0	1
Post total	6	15	8	3	0	1	7	9	12	3	7	19	5	1	0	0	10	14	7	1	0	13	15	3	1	0	3	19	6	3	0	1
Overall percent	17	49	24	8	0	3	28	27	32	10	21	55	18	3	1	1	34	48	17	1	0	38	51	8	3	0	13	48	28	8	0	3
Pre percent	15	51	23	8	0	3	33	26	28	10	21	51	21	3	3	3	36	51	13	0	0	36	54	8	3	0	15	38	36	8	0	3
Post percent	19	47	25	9	0	3	22	28	38	9	22	59	16	3	0	0	31	44	22	3	0	41	47	9	3	0	9	59	19	9	0	3

Course & Prior Chem	Q31 SA	A	N	D	SD	B	Q32 SA	A	N	D	SD
DT 203 Pre (Chem)		6	1	2	2			11			
DT 203 Pre (No Chem)		3	3	1				7			
DT 203 Post (Chem)		5	2	2				9			
DT 203 Post (No Chem)	1	3	1	2				7			
DT227 pre (Chem)	1	2	1	1				5			
DT227 pre (No Chem)		1	2	1				4			
DT 227 post (Chem)	1		2					3			
DT 227 post (No Chem)	1		3					4			
DT 299 post (Chem)	1		1					2			
DT 299 post (No Chem)											
DT222 pre (Chem)		2		1				3			
DT222 pre (No Chem)		2	1	1		1		5			
DT222 (3) AND DT 227 (1) pre (repeats)		2	2					4			
DT 222 post (Chem)		1		1				2			
DT 222 post (No Chem)		2	2	1				5			
Overall Total	5	29	21	13	2	1	0	71	0	0	0
Pre total	1	18	10	7	2	1	0	39	0	0	0
Post total	4	11	11	6	0	0	0	32	0	0	0
Overall percent	7	41	30	18	3	1	0	100	0	0	0
Pre percent	3	46	26	18	5	3	0	100	0	0	0
Post percent	13	34	34	19	0	0	0	100	0	0	0

Course & Prior Chem	Q33 SA	A	N	D	SD	B	Q34 SA	A	N	D	SD	B
DT 203 Pre (Chem)			4	6	1		1	4	2	3		1
DT 203 Pre (No Chem)		2	2	3				3	2	1	1	
DT 203 Post (Chem)		1	4	4				6	3			
DT 203 Post (No Chem)		1	4	2				4	1	2		
DT227 pre (Chem)		1		4				2	3			
DT227 pre (No Chem)			4				2	1		1		
DT 227 post (Chem)				1	2		1	2				
DT 227 post (No Chem)		1	1	1	1			2	1	1		
DT 299 post (Chem)				2			1	1				
DT 299 post (No Chem)												
DT222 pre (Chem)	1		1	1				2	1			
DT222 pre (No Chem)		1		3		1		4				1
DT222 (3) AND DT 227 (1) pre (repeats)		1	1	2				1	3			
DT 222 post (Chem)				1	1			2				
DT 222 post (No Chem)			2	1	1	1	1	1	2	1		
Overall Total	1	8	23	31	6	2	6	35	18	9	1	2
Pre total	1	5	12	19	1	1	3	17	11	5	1	2
Post total	0	3	11	12	5	1	3	18	7	4	0	0
Overall percent	1	11	32	44	8	3	8	49	25	13	1	3
Pre percent	3	13	31	49	3	3	8	44	28	13	3	6
Post percent	0	9	34	38	16	3	9	56	22	13	0	0

Course & Prior Chem	Q35 SA	A	N	D	SD	B	Q36 SA	A	N	D	SD	B
DT 203 Pre (Chem)		7	4					6	5			
DT 203 Pre (No Chem)		2	2	3				2	4	1		
DT 203 Post (Chem)	1	4	4				1	6	2			
DT 203 Post (No Chem)		2	4	1			2	4		1		
DT227 pre (Chem)	1	1	3				2	3				
DT227 pre (No Chem)		1	2	1			1	1	1			1
DT 227 post (Chem)	1	2					1	1	1			
DT 227 post (No Chem)			4					2	2			
DT 299 post (Chem)	1		1				1	1				
DT 299 post (No Chem)												
DT222 pre (Chem)		1	1	1				1	1		1	
DT222 pre (No Chem)		2	1	1		1	1	2	1			1
DT222 (3) AND DT 227 (1) pre (repeats)		1	2	1				4				
DT 222 post (Chem)		1	1					2				
DT 222 post (No Chem)			5				2	2	1			
Overall Total	4	24	34	8	0	1	11	37	18	2	1	2
Pre total	1	15	15	7	0	1	4	19	12	1	1	2
Post total	3	9	19	1	0	0	7	18	6	1	0	0
Overall percent	6	34	48	11	0	1	15	52	25	3	1	3
Pre percent	3	38	38	18	0	3	10	49	31	3	3	5
Post percent	9	28	59	3	0	0	22	56	19	3	0	0

Course & Prior Chem	Q37 SA	A	N	D	SD	B	Q38 SA	A	N	D	SD
DT 203 Pre (Chem)		2	4	5			6	4			
DT 203 Pre (No Chem)	2	2	2	1			3	3	1		1
DT 203 Post (Chem)		5	2	2			4	3			2
DT 203 Post (No Chem)		4	2	1			4	2			1
DT227 pre (Chem)		1	1	2	1		4	1			
DT227 pre (No Chem)		2	1	1			1	3			
DT 227 post (Chem)				2	1		3				
DT 227 post (No Chem)		1	2	1			1	2	1		
DT 299 post (Chem)				2			2				
DT 299 post (No Chem)											
DT222 pre (Chem)		1	1	1			1	2			
DT222 pre (No Chem)		1		3		1	3	2			
DT222 (3) AND DT 227 (1) pre (repeats)	2			2			2	2			
DT 222 post (Chem)		1	1				2				
DT 222 post (No Chem)		1	2	2			3	2			
Overall Total	4	21	18	25	2	1	39	26	2	0	4
Pre total	4	9	9	15	1	1	20	17	1	0	1
Post total	0	12	9	10	1	0	19	9	1	0	3
Overall percent	6	30	25	35	3	1	55	37	3	0	6
Pre percent	10	23	23	38	3	3	51	44	3	0	3
Post percent	0	38	28	31	3	0	59	28	3	0	9