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# Learner Experiences of Online Pre-lecture Resources for an Undergraduate Introductory Chemistry Course – A Case Study Informed by Phenomenography

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## Introduction

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 and Sheehan, 2009; Seery, 2009a; Reid, 2008). The nature of the material taught and the pedagogical approaches used on introductory chemistry courses at second and third level has been scrutinised recently and several 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.

*The Effect of Cognitive Load on Learning*

Several reviews have been published by educational psychologists that address how new information is assimilated (Sweller and Chandler, 1991; Baddeley, 2003; Artino, 2008; Ayres and Paas, 2009). This area of research has informed education researchers in science (St. Clair-Thompson and Botton, 2009) and chemistry (Johnstone, 1997; Reid, 2008). A model of the way in which information is processed developed by Reid (2008) and Johnstone (1997) describes how 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. As working memory capacity is finite, when it is exceeded, a situation described as “cognitive overload” results. It has also been established that the existence of a relationship to previous knowledge and to experience (a context) is valuable in assisting the transition of information to long term memory (Ausubel 1968; Reid, 2008).

*Pre-lecture Resources (Paper-based and Online)*

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, 2009a). 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 reducing the cognitive load then experienced by students during their lecture. Johnstone and Reid and co-workers described dealing with a situation where incoming students had a diverse range of prior knowledge of chemistry (Sirhan *et al.*, 1999). In this paper and in subsequent work (Sirhan and Reid, 2001, 2002), the authors described how they used “Chemorganiser” worksheets as pre-lecture activities that introduced key terms. When the pre-lecture resources were used with students who had little or no prior knowledge only, no significant difference between the exam marks of this cohort of students and the group who had prior knowledge of chemistry was observed. When the pre-lectures were removed, a significant difference between the results returned.

The development of web-based 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 more effectively during lectures (Collard *et al.*, 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). In other disciplines, examples have been reported for pre-lecture activities in biology (Burke da Silva and Hunter, 2009) and physics (Chen *et al.*, 2010; Deslauriers *et al.*, 2011) as well as psychology (Narloch *et al.*, 2006; Lineweaver, 2010). A related recent development has been the concept of the inverted or "flipped" lecture which incorporates a great deal of pre-lecture activity so that contact time with lecturers can be used for active engagement (Bates and Galloway, 2012).

*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 and Wellington, 2001). 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 and 2010). In addition, some familiar terms (for example, "neutral") often have other meanings when used in a scientific context (Jasien, 2010). 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 and 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.

*Perceptions of Learning Environments in Chemistry*

The Higher Education Academy have produced a review of the undergraduate learning experience in chemistry in the United Kingdom and the student responses showed that the nature of their learning experience appeared not to differ much across institutions (Gagan, 2009). They rated tutorials as the most effective teaching method and practical work as the most enjoyable one. 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 for chemistry at third level in the United Kingdom. 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 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 *et al.* (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. Lyall (2010) examined a switch to a less structured laboratory programme and Daly and Bodner (2005) reported 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*

Approaches to learning have been classified into three categories that are usually observed; surface, strategic and deep. Initially, the identification of surface and deep learners was reported by Marton and Säljö (1976a, 1976b) and an additional category called the strategic (or "achieving") approach was added as a result of further research (Biggs, 1979; Ramsden and Entwistle, 1981). Table 1 below summarises the main characteristics of each approach to learning.

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

| 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. |

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 (Entwistle and Ramsden 1983; Kember 2004). 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 *et al.*, 1999).

**Rationale for This Study**

Chemistry lecturers of first year students are required to introduce learners to a wide range of chemistry principles so that they are prepared for more specialised modules when they progress to second year. In the Irish education system, science students at third level are made up of a range from learners who have achieved good performances in chemistry at second level through to those who have not studied chemistry previously. A study of first year chemistry undergraduates undertaken at Dublin Institute of Technology (DIT) by Seery (2009a, 2009b) found that there was a significant difference, consistent over a five year period, between the average end of year examination marks for the group of students who had studied chemistry at second level and those who had not. The students who had studied chemistry previously achieved a mark that was on average 14% higher in their end of module examination and this research showed that prior knowledge was the sole predictor for this mark. This work led to the decision to implement the use of web-based pre-lecture resources intended to support learners without prior knowledge in chemistry. A suite of nine online pre-lecture resources was developed and implemented for 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 and incorporated short quizzes. In addition, feedback was provided during lecture sessions and students' understanding was further probed with in-class questions (Seery and Donnelly, 2012). Quantitative analysis which focussed on the learners' performance in their module assessments and the extent to which they accessed the pre-lecture resources was also performed.

The investigation described in this paper complements the work of Seery and Donnelly (2012) by undertaking a qualitative analysis of the participants' perception of the effects of the implementation of the pre-lecture resources on their learning.

**Aim and Research Question**

The aim of this research was to probe students' perceptions and experiences of the web-based pre-lecture resources implemented in relation to their learning and their attitudes towards chemistry. 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 research aim was sub-divided into three questions, shown below, which are ranked in order of the importance attributed to them during this study:

1. What are the variations in learner experience of using the online pre-lecture resources in introductory chemistry for first year undergraduates at DIT?
2. What are the qualitatively different ways in which students perceive their learning environment for the introductory chemistry module?
3. How do the learners' perceptions of their use of the online pre-lecture resources compare with those of the academic who designed them?

*Limitations and Scope*

The scope of the study is that it examines one cohort of students in one higher education institution and one new learner support strategy that was introduced. The conclusions from the research are specific to first year undergraduates studying chemistry on level 8 courses in DIT. However, these results should be useful in informing similar projects in other colleges or larger scale investigations across several higher education institutions.

**Research Design**

The research questions in this study are rooted in the constructivist epistemology as they deal with investigating how individual students approach their learning and with understanding how they perceive their learning environment. 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. (Crotty, 1998). The interpretivist paradigm is the most appropriate for this work and some of the assumptions associated with this theoretical perspective are that meaning is constructed by individuals as they engage with the world they are interpreting (Creswell, 2003) and that research will be small-scale and will be interpreted in a particular context rather than generalised. One shortcoming of the interpretivist paradigm is that it largely neglects the effect of external forces on behaviour and events (Cohen *et al.*, 2000).

As the research questions being examined are framed in the interpretivist paradigm, the associated methodologies considered were grounded theory, ethnography and phenomenography (Crotty, 1998). Phenomenography was the methodology selected as it was found to be the most appropriate choice to allow the research questions to be answered. Phenomenography can be applied when;

- The perspective and experiences of the learners, not the researcher, are of interest.
- 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).

Phenomenography '*focuses on identifying and describing the qualitatively different ways in which people understand phenomena in the world around them*' (Franz *et al.*, 1997). It was developed in the 1960s and 1970s by Marton and his fellow researchers as an approach for examining student learning. Phenomenographic outcomes do not show the richness of the data, only variation, for which there is clear evidence from the transcripts analysed (Bowden, 2005). 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).

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 (Åkerlind, 2002). 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.

Developmental phenomenography was the approach used in this study. The purpose of this type of 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; Åkerlind, 2005; Bowden and Green, 2005). 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.

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 *et al.* (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 this interpretation has been applied to this work.

The methods employed were an attitudes survey and semi-structured interviews and they were applied so that qualitative analysis of the data collected could be performed.

**Participants**

The learners who participated in this research were a cohort of 49 first year undergraduates (28 male and 21 female) who were enrolled on either a chemistry- or physics-based level 8 science degree at DIT in September 2010. 25 of these students had studied chemistry at senior cycle level in secondary school. All students were undertaking a 5 European Credit Transfer System (ECTS) credit Introductory Chemistry module over their first semester. 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 covered so that they can engage in more specialised topics in second year.

Phenomenographic interviews were performed with nine participants when the module had been completed. Purposeful sampling was applied as the learners were selected on the basis of maximising variety among the participants and ensuring that a range of experiences would be captured. Criteria used included programme of study, prior experience of chemistry, overall performance at second level, 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. Details about the participants are presented in Table 2 below.

**Table 2** Information on interview participants (gender, prior chemistry knowledge and module test and examination grades)

| **Gender** | **Chemistry prior knowledge (second level)** | **Degree course focus** | **Mid-semester test grade (%)** | **Summative exam grade (%)** | **Additonal Comments** |
|---|---|---|---|---|---|
| Female | ordinary level, C1 | physics | 62 | 41 | |
| Female | ordinary level, A2 | chemistry | 55 | 35 | |
| Female | No | chemistry | 33 | 35 | Mature student |
| Male | No | physics | 74 | 68 | |
| Male | higher level, D1 | chemistry | 67 | 35 | Registered learning difficulty (dyslexia) |
| Female | No | chemistry | 22 | 40 | |
| Male | higher level, C2 | chemistry | 68 | 57 | |
| Male | No | chemistry | 73 | 81 | |
| Male | higher level, C3 | chemistry | 60 | 46 | |

The surveys were completely anonymously and the identities of interview participants were anonymised on the transcripts. British Educational Research Association guidelines (BERA, 2004) were followed and students were provided with information on the project and asked to sign consent forms before participating in this study. A book voucher to the value of 15 euro was provided to compensate each interview participant for their time. This was considered to be an appropriate way of acknowledging their input.

**Data Collection**

*Attitudes Survey*

A copy of the survey developed is presented in the Appendices (Appendix 1). It is a Likert scale attitudes survey which contains 35 statements. Additional questions on the first page relate to the degree course the student is enrolled in and the science subjects they had studied at second level. A section for recording optional comments is also included. 14 questions from the Colorado Learning Attitudes About Science Survey (Barbera *et al.*, 2008) have been incorporated and permission to do so was obtained from the first author. Several other statements used were based on examples provided in Reid (2006). The remainder of the survey was developed by the authors and relates to online learning resources, context and cognitive load.

The survey was administered in a paper-based format during tutorial sessions. It was completed anonymously by 43 students (6 were absent) in the second week of the semester on September 30th 2010. One survey 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 directed that "agree" be selected as the response and, if this was not done, it was assumed that the participant was not reading the survey with sufficient care (Barbera *et al.*, 2008). In total, 39 surveys (80% of total cohort) were analysed. The same survey was administered in week one of the second semester on 3rd February 2011. The Introductory Chemistry module that was the focus of this study was complete at this stage and students had taken the summative examination and received their results. 36 students completed the survey and, of these, 4 participants did not respond as directed to statement 32. Therefore, 32 surveys (65% of total cohort) were analysed.

The two stages at which the students were asked to complete the survey have been labelled "pre-module" and "post-module" 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 online pre-lecture resources had been first introduced to the students. However, it does capture student attitudes towards the beginning of the module.

*Phenomenographic Interviews*

Individual semi-structured interviews were performed with nine participants in the first four weeks of semester two. The open-ended questions prepared are presented in the Appendices (Appendix 2). Some of the questions were developed by reformatting the survey statements as open-ended questions while others were adapted from existing studies which used phenomenography (Walsh, 2009) or qualitative methods (Thompson *et al.*, 2005) to analyse student perceptions of their learning environment. The interviews 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 however.

*Semi-structured Interview with Module Lecturer*

The researcher who had developed and implemented the online pre-lecture resources agreed to be interviewed at the end of the relevant module. The questions used were adapted from those employed with the students and were expanded on to include resource design considerations.

## Data Analysis

*Attitudes Survey*

The survey responses were collated according to whether respondents had studied chemistry before or not and which course of study they were following. Their percentage selections of each of the five possible responses on the Likert scale for each statement were determined. The results were entered into spreadsheet and the summary of the total responses to each statement were compiled in a table which is presented in the Appendices (Appendix 3). 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 the academic year. As the surveys were anonymous, 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 Phenomenographic Interviews*

As there is no prescriptive format for conducting phenomenographic research, when phenomenography is applied, it is essential that the procedure adopted is documented and the individual variations in the method used are explained (Bowden and 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" (Åkerlind, Bowden and Green, 2005:82) and non-critical variation occurs within a way of experiencing and therefore does not distinguish between ways of experiencing.

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" (Åkerlind, 2005). Considering the entire transcript is proposed to give a holistic view (Bowden, 1996). As this study adopted the developmental phenomenography approach described by Bowden (2005), the entire transcripts were considered when establishing categories of description.

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 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 and 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 (Åkerlind, 2005). This work followed the method described by Bowden (2005) and the structural relationship between the categories of description was not 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, Åkerlind (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. For this particular study, the first author worked alone during the data analysis.

*Validity and Reliability*

Two methods of checking validity, communicative and pragmatic validity, are commonly used in phenomenographic research (Åkerlind, 2005). Communicative validity 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 *et al.*, 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 (Åkerlind, 2005). In this study, communicative validity was achieved using the three methods described.

Two checks on reliability that are often used in qualitative, interview-based research are coder reliability checks and dialogic reliability checks and they are employed to varying degrees within phenomenographic research. 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 them and providing examples to illustrate them (Åkerlind, 2005). 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 *et al.,* 2007). In this study, the authors have endeavoured to show evidence of interpretive awareness at these stages.

*Method of Interview Analysis*

A spreadsheet containing the relevant metadata on each interview (date, participant details, participant code used in transcripts) was prepared. The interview recordings were transcribed verbatim and the transcripts were then examined for errors, unclear meanings and inconsistent statements and were then checked against the recordings. The transcripts were formatted for easy reference and marking (lines were numbered and 1.5 line spacing was applied).

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 were then developed. The analysis was iterative and required constant comparison to ensure internal consistency (comparing similarly categorised transcripts to see if there was any variation). Categories of description were reviewed and tested against the data (the transcripts) until no further adjustments were necessary. Categories of description were 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. Marton and Pong (2005) observe that referential and structural dimensions, though different, are entwined. It was important to concentrate on the transcripts and emerging categories of description as a set instead of individually so that a focus on the collective experience was preserved (Åkerlind, 2005). A detailed description of the student interview data analysis process is provided in the Appendices (Appendix 4).

## Research Findings

*Attitudes Survey*

All details for the survey responses have been compiled (McDonnell, 2011) and a summary of the response data for a selection of statements considered to be particularly relevant to the research question is presented in Table 3. A version of this table that includes all of the statements from the survey is provided in the Appendices (Appendix 3). In order to simplify the presentation of the findings, the percentages of “agree” and “strongly agree” replies have been combined, as have the “disagree” and “strongly disagree” responses. Pre- and post-responses to each statement were compared and, when a difference of greater than 10% was observed, this has been presented. When the difference was less than 10%, the overall average from the pre- and post- surveys has been used. The number in front of each statement refers to the original survey and the statements have been reordered from there so that they are grouped into similar themes. A grey background is used in the table to highlight statements for which the combined “agree” and “strongly agree” total was over 60%.

**Table 3** Data extracted from surveys conducted on attitudes to learning chemistry

| **Statement on Attitude to Learning Chemistry from Survey** | **Summary of Responses** (values are averages of pre and post |
| --- | --- |

| | |
|---|---|
| | responses unless noted otherwise) |
| **Context** | |
| 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 |
| **Cognitive Overload** | |
| 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 |
| **Pre-Lecture Information and Relationship to Prior Knowledge** | |
| 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 |
| **Multimedia Tools and Textbooks and Internet** | |

| **Accessibility** | |
|---|---|
| 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 |

*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 their lecture room. For 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. As a result of the response to this statement in the pre-module survey, a related question was added to those to 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 chemistry at second level would have been revising familiar material in lectures. The responses to statement 23 demonstrated a similar trend and an increase from 61% to 88% was recorded.

*Attitudes to Pre-Lecture Information and Relationship to Prior Knowledge*

The replies 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. All of these responses support the rationale provided for introducing the online pre-lecture resources (Seery and Donnelly, 2012).

*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. 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. However, it became apparent from the student interviews that those who were relying on accessing the internet in college had experienced some difficulties.

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.

Each survey included spaces provided for optional comments. Not many students used this facility and the remarks from the seven who did so were analysed. It was found that each point made was also raised at least once during the course of the semi-structured interviews that followed (Mc Donnell, 2011). This methodological triangulation demonstrates 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 *et al.*, 2000).

*Phenomenographic Interviews with Students*

These interviews with nine students were the main component of this investigation and they were designed to attempt to answer research questions 1 and 2.

*Learners' Experiences of Using the Online Pre-lecture Resources*

The unit of analysis used 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 describe the qualitative variation that was discovered in the ways learners experienced using the pre-lecture resources.

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

| **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 |

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 and 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 and Pong, 2005:336). The resulting outcome space is presented in Table 5 below.

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

| 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 |

Each category of description will now be described 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. (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 or not. 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.*

This information about some students skipping straight to the quiz section of the resource was very useful in informing further redesign of the pre-lecture resources.

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 after resource 3 when they were told by the lecturer that the quiz marks from then on would count 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 examination. These students also said 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. 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 examination. Some students completed all of the resources but some did not. 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 the lecturer was talking about.*

The students who belonged to this category were found to have all already studied chemistry at second level 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 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 but instead were concerned with understanding the subject. Some students in this category had prior knowledge from second level 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 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.*

The next excerpt illustrates that these learners approached the resource and the quiz that followed as an opportunity to gain some knowledge on a topic or concept and, therefore, they did not want to get a correct answer in 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, Mo, 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.*

*Referential and Structural Differences Between the Categories of Description*

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 second 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. 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 were referred to in the introduction.

*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 intention is that students will find that they have no option other than to learn.

*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 was students' perceptions of their learning environment for their Introductory Chemistry module. In this study, the students' perception of their learning environment is taken to mean the participants' perception of how their module was presented to them and of what is expected from them in their study of chemistry. Categories may be described using two components; how their environment is described and what is focused on. The set of categories presented in Table 6 describes the qualitative variation discovered in the ways students perceived their learning environment for introductory chemistry.

**Table 6** Categories of description for students' perceptions of their learning environment for their introductory chemistry module.

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

As described for the previous unit of analysis, these three categories of description formed a nested hierarchy. An outcome space based on these categories was developed by further differentiating experiences into structural and referential dimensions. The referential aspect 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.

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

| Category of Description | 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 |

*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: *Because the exam was after Christmas, you think you have loads of time 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.*

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. Learners focussed on the importance of getting good notes from their lecturer and knowing the information required 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.

*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 did on practicing questions and calculations from tutorial worksheets and from past examination papers. Also, it was clear to them why they needed to study chemistry as part of their degree. 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. 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 did not 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. 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. These students also discussed how their confidence of their knowledge of chemistry had increased over the course of the module:

Student E: *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.*

*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. 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 Säljö, 1976a and 1976b) which leads to lower level learning outcomes. These learners' 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 of 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 and Gillies, 2005) and a range of initiatives to address this problem have been described in the literature, including learning portfolios (Commander and 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 and 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 DIT 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. 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 and Ramsden, 1983). Thus, implementation of a constructively aligned curriculum 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 themselves 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.

*Interview with Module Lecturer*

This interview allowed the third research question to be addressed. The data from the lecturer interview was collated into three main themes and the analysis of this interview is presented using these themes.

*i) Descriptions That Allowed for Comparison with Student Accounts of Their Experiences*

The similarity of 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.

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

| **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. |

The correspondence in general between the lecturer and student accounts 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, when this dissonance occurs, it does not invalidate the data.

*ii) 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.
- 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:

> *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.*

*iii) Reflections on the Learning Environment*

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. The main themes that emerged were as follows:

- The process of designing the pre-lecture resources required that an analysis of cognitive load (the number of new terms and concepts) be performed on each lecture and this resulted in a re-evaluation of lectures from the perspective of a novice.
- This reconsideration of the learning environment included evaluating a possible 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 had 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 instead of knowledge provider.

**Conclusions**

The pre- and post-module surveys provided data on attitudes to a number of aspects of the learning environment. 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.

Analysis of the phenomenographic interview transcripts allowed a description of the qualitatively different ways in which learners experienced using the pre-lecture resources to emerge 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 should 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 arrived at. 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 attitudes surveys showed that perceived irrelevance contributed to a learner experience that was aligned with a surface approach to learning. To ensure that the intended module learning outcomes are met, strategic alignment of learning outcomes, assessments and learning activities and teaching methods should encourage strategic learners to opt for a deep approach.

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. 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.

**Implications for Other Higher Education Institutions and Further Work**

Based on the success of this pilot implementation of online pre-lecture resources in a first year chemistry module, the following year (2011-12) a series of ten similar resources were developed by the first author to support learners she was teaching in semester two of first year (McDonnell *et al.*, 2012). It is intended that quantitative analysis will be performed on attitudes surveys administered over a three year period as sufficient data will be available. 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. The finding that roughly equal numbers of these students liked using multimedia tools (60%) as liked using a textbook (58%) to help them to study chemistry is an interesting one and it is hoped to investigate it further.

This study has provided important findings in relation to student experiences of an intervention designed to reduce their cognitive load. It is apparent from this research and that of Seery and Donnelly (2012) that this approach would be useful in any teaching environment where there is a variation in prior learning and also as a method of allowing lecture sessions to become more focussed on student understanding and active participation. Another outcome of this study that is of wider relevance is that issues in relation to transition to third level education and the development of metacognitive skills have been identified.

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**Appendix 1** Attitudes survey used pre- and post-module.

**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.**
**It will take approximately 10 minutes to complete this survey.**

**Course Code: ___________________**

**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 at second level:

Biology ☐
Chemistry ☐
Physics ☐
Physics and Chemistry combined ☐

**What are your opinions about learning chemistry to date?**

- 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.

*Please tick ONE box on each line to represent 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 2** Opening statement and questions used for student interviews.

*Opening statement (modified from* Ireland, Joseph, Tambyah, Mallihai M., Neofa, Zui, & Harding, Terry. *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.)
*I am carrying out 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.*

**Opening Questions (5 minutes maximum)**

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 minutes approximately)**
(The list of pre-lecture resource topics was provided at this stage)

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, and
   b) when one was not available.
   A follow up question on whether the feedback from the quiz was useful was asked.
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 did not?
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 have done 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 minutes approximately)**

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 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 if so.

**Perceptions of the Learning Environment (10 minutes approximately)**

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
PL 8 Introduction to thermodynamics and first law
PL 9 Enthalpy and description of thermochemical equations

**Appendix 3** Summary of responses to each statement on the attitudes survey.

| **Statement on Attitude to Learning Chemistry** | **Summary of Responses** (values are averages of pre and post responses unless noted otherwise) |
|---|---|
| 4) I am enjoying chemistry | 68% agree/strongly agree and 27% neutral |
| 5) I feel I am coping well with chemistry so far | 60% agree/ strongly agree and 21% neutral |
| 6) I have found chemistry easy so far | 27% agree/strongly agree, 34% neutral and 36% disagree/strongly disagree |
| 7) Having studied chemistry at second level makes it easier to learn at college | 51% agree/strongly agree and 27% neutral |
| 8) Sometimes I feel that too much new information is presented in a chemistry lecture | 31% agree/strongly agree and 26% neutral in **pre** survey |
| | 51% agree/strongly agree and 34% neutral in **post** survey |
| 9) It is important to know why I need to learn about a topic. | 88% agree/strongly agree and 7% neutral |
| 10) I am getting worse at chemistry | 75% disagree/strongly disagree and 20% neutral |
| 11) I understand what we have done so far in chemistry lectures | 69% agree/strongly agree and 21% neutral |
| 12) Chemistry is definitely "my" subject | 91% agree/strongly agree and 7% neutral |
| 13) It is important to know how a topic relates to the "real world" | 85% agree/strongly agree and 13% neutral |
| 14) It is important to know how a new chemistry topic relates to what I already know | 85% agree/strongly agree and 13% neutral |
| 15) I want to do as well as I can in chemistry | 95% agree/strongly agree and 3% neutral |
| 16) It is clear to me why I need to study chemistry as part of the degree I chose. | 66% agree/strongly agree and 15% neutral in **pre** survey |
| | 85% agree/strongly agree and 3% neutral in **post** survey |
| 17) I find that a textbook is useful when I am studying chemistry | 55% agree/strongly agree and 34% neutral |
| 18) I like to use textbooks to help me to study chemistry | 58% agree/strongly agree and 28% neutral |
| 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 and 15% neutral in **post** survey |
| 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 | 80% agree/strongly agree and 10% neutral in **pre** survey<br>60% agree/strongly agree and 28% neutral in **post** survey |
| 21) I like to use multimedia tools to help me to study chemistry | 60% agree/strongly agree and 24% neutral |
| 22) Chemistry is made up of many disconnected topics | 75% disagree/strongly disagree and 20% neutral |
| 23) I find that if too many new terms and concepts are introduced in one lecture, I | 61% agree/strongly agree and 21% neutral in **pre** survey |

| | |
|---|---|
| struggle to understand | 88% agree/strongly agree and 3% neutral in **post** survey |
| 24) I find that if too many new terms and concepts are introduced in one lecture, I lose motivation and interest | 47% agree/strongly agree and 23% neutral |
| 25) A big problem in learning chemistry is being able to memorise all of the information I need to know | 66% agree/strongly agree and 24% neutral |
| 26) I think about the chemistry I experience in everyday life | 36% agree/strongly agree and 26% neutral in **pre** survey |
| | 25% agree/strongly agree and 28% neutral in **post** survey |
| 27) My friends and family think that chemistry is a difficult subject | 76% agree/strongly agree and 18% neutral |
| 28) It is helpful to know in advance what topics each chemistry lecture will be about | 82% agree/strongly agree and 17% neutral |
| 29) It is helpful to have had some of the terms explained in advance of a chemistry lecture | 89% agree/strongly agree and 8% neutral |
| 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 | 53% agree/strongly agree and 36% neutral in **pre** survey |
| | 68% agree/strongly agree and 19% neutral in **post** survey |
| 31) Nearly everyone can understand chemistry if they work at it. | 48% agree/strongly agree and 30% neutral |
| 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. | 100% agree |
| 33) A lot of the material in chemistry does not make sense to me so I just memorise the information. | 52% disagree/strongly disagree and 32% neutral |
| 34) If I get stuck on a chemistry question on my first attempt, I usually try to figure out a different way that works. | 52% agree/strongly agree and 28% neutral in **pre** survey |
| | 65% agree/strongly agree and 22% neutral in **post** survey |
| 35) The skills I use to understand chemistry can be helpful to me in my everyday life | 40% agree/strongly agree and 48% 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 and 31% neutral in **pre** survey |
| | 78% agree/strongly agree and 19% neutral in **post** survey |
| 37) When I am answering chemistry questions and problems, I often do not really understand what I'm doing | 36% agree/strongly agree and 25% neutral |
| 38) I can access the internet easily when I need to | 92% agree/strongly agree and 3% neutral |

**Appendix 4** 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).

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 and Ingerman, 2008). It was necessary to analyse the transcripts using two different units of analysis in order to answer the first two research questions in this study 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 focused 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 the researcher's 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), the researcher 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 the researcher felt she had sufficient familiarity with the data, she prepared a set of notes that recorded the information that she 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, she 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, she then worked with the notes and the transcripts to look for the critical similarities and differences between the transcripts. She added additional notes on cases of agreement and variation on what she 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?' ". A Microsoft Excel worksheet was prepared to record the similarities and differences between transcripts and the researcher then began to describe them while referring back to the transcripts constantly.

From this, tentative categories were formed and, one this was achieved, the categories and transcripts were examined repeatedly for the structure of the categories. For each category that had been identified, the researcher 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 the researcher felt would give substance and support to the categories.