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9 Scaffolding for cognitive overload using pre-lecture e-resources (SCOPE) for first year chemistry undergraduates

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Abstract

The aims of this project were: to develop additional online pre-lecture resources for first year chemistry undergraduates at level 7 and level 8 to complement those prepared in the 2010/2011 academic year for level 8 students by Dr Michael Seery as part of his teaching fellowship, and to evaluate the effect of implementing the resources this year by analysing quantitative (test and exam results) and qualitative (pre- and post-implementation surveys and focus group interviews) data. Ten pre-lecture activities on organic chemistry were prepared and used with 87 level 8 students in Semester 2 and ten more on general chemistry topics have been developed and will be implemented with level 7 students in September 2012. Analysis of the mid-semester test and examination results of the students with whom the resources were used in semester 2 showed that, among groups with similar CAO points levels, the gap in performance between those who had and had not studied chemistry at Leaving Certificate was eliminated. The surveys and focus groups undertaken revealed that learners felt more confident and that they could focus more in the lecture when they had completed a pre-lecture activity.

Keywords: cognitive load, first year experience, pre-lecture resources, prior learning

Introduction

How learners process information

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; Reid 2008; Seery 2009). As a result, it has been recommended that greater consideration should be given to cognitive load and to ensuring that learners are given the opportunity to embed knowledge in their long-term memory by means of processing new concepts in their working memory (Childs 2009; Johnstone 2010; Reid 2008). The way in which new information is assimilated has been studied by educational psychologists for some time and several reviews have been published (Artino 2008; Ayres and Paas 2009; Baddeley 2003; Sweller and Chandler 1991). This area of research has also informed science and chemistry education researchers and a model of how information is processed developed by Reid and Johnstone is presented in Figure 9.1 (Johnstone 1997; Reid 2008). It shows that new information must (i) first be perceived as such and can then (ii) be processed in the working memory, which has a limited capacity, and, (iii) under the correct conditions, will then be assimilated into long-term memory.

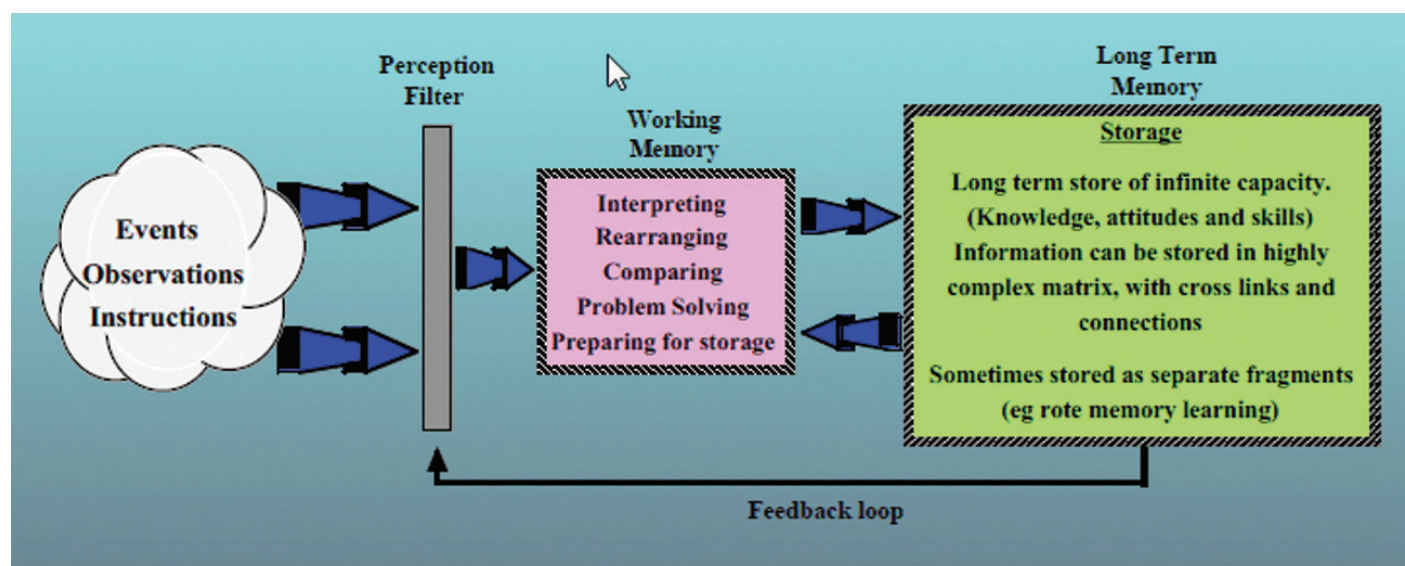


Figure 9.1 An Information Processing Model (reproduced from Reid 2008 and after Johnstone 1997)

Pre-lecture activities

As working memory capacity is finite, when it is exceeded, a situation described as cognitive overload results. 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 2009). One of the strategies that can be implemented to address this problem is to provide learning materials in advance of the lecture with the aim of then reducing the cognitive load experienced by students during their lecture. Substantial work in this area was carried out by Johnstone and Reid when they sought to address a situation where incoming students had a diverse range of prior knowledge of chemistry (Sirhan et al. 1999; Sirhan and Reid 2001). When paper-based pre-lecture resources were used with students who had little or no prior knowledge, 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-lecture resources were removed, there was a significant difference between the results. A previous study at Dublin Institute of Technology also demonstrated the effect of prior knowledge of chemistry as it was found that there was a significant difference between the examination achievement in first year of undergraduates who had and had not studied chemistry at second level (Seery 2009).

The development of electronic, rather than paper-based, pre-lecture resources incorporating the principles of cognitive load theory can be used to reduce the burden on the working memory of novice learners. Collard, Girardot and Deutsch (2002) have applied this method to chemistry as have Slunt and Giancarlo (2004). This approach has also been used recently and very effectively at Dublin Institute of Technology (Seery and Donnelly 2012).

Project aims

The aims of this project were:

1. To develop additional online pre-lecture resources for first year chemistry undergraduates at level 7 and level 8 to complement those produced last year for level 8 (Seery and Donnelly 2012).
2. To evaluate the effect of implementing these resources by analysing data quantitatively (test and exam results) and qualitatively (pre- and post-implementation surveys and focus group interviews).

The e-resources were designed to:

- reduce cognitive load by introducing some new terms and concepts before the lecture;
- incorporate worked examples to scaffold students' learning;
- provide short online test questions using the college virtual learning environment (VLE) with immediate feedback so that students could identify areas of difficulty.

The anticipated benefit was that that the gap in performance often observed in first year between learners who have and have not studied chemistry at Leaving Certificate would disappear. This was shown to occur last year in a level 8 first semester module (Seery and Donnelly 2012) and it was anticipated that this positive effect could be extended to our first year teaching.

Outline of Project

Student engagement

Ten online pre-lecture resources on introductory organic chemistry were developed and then used with 87 level 8 students in Semester 2. A small proportion of their continuous assessment mark was allocated to the associated online tests to encourage learners to participate. The average uptake across the ten resources employed was 92% and the average quiz mark was 73%. This relatively high average mark reflects the intention that the questions would be at a suitable level to probe a basic comprehension of the terms and concepts introduced. The design of the resources produced followed the principles established by Michael Seery the previous year and differed only in that an audio commentary was not added and the pre-lecture information was distributed in a paper format as well as electronically. Ten online pre-lecture resources have also been developed on general chemistry for use with level 7 students and they will be implemented in September 2012.

Test and examination performance

Analysis was performed on the mid-semester test and examination results for the relevant level 8 module and their relationship to the prior chemistry knowledge of these students. The cohort of level 8 students who used the resources this year was somewhat different to previous years in that the uptake for a chemistry programme (DT299) that was launched in 2010 had increased significantly and, compared to the rest of the class, the 24 students on that course had a higher average performance at second level (397 CAO points) and a higher proportion of them had studied chemistry at Leaving Certificate (84%). The remaining 56 students were drawn from three different programmes and were more representative of the type of students who were usually taught on this module as they had an average of 367 CAO points (30 points lower than the DT299 group) and only 50% of them had studied chemistry at second level.

It was found that a significant difference in module test and examination performance between those who had and had not studied chemistry at Leaving Certificate did occur when the 24 students from DT299 with the uncharacteristic profile (higher points and 84% with prior chemistry knowledge) were included in the analysis. The average test marks were 56% and 41% respectively for those who had and had not prior knowledge while examination marks were 58% and 37%.

Average CAO points were 372 and 359 for those with and without prior knowledge respectively, but the difference was not found to be significant. However, it did seem reasonable to perform an analysis when the DT299 group had been excluded for comparison. In this case, it was found that the difference in average CAO points between those who had (355 points) and had not (350 points) studied chemistry at second level was much lower and the variation in performance for the organic chemistry sections of the module mid-semester test and examination for those with and without prior chemistry knowledge were found to no longer be significant (49% and 42% respectively in the test and 49% and 36% in the examination).

Although there are some qualifications related to this analysis, it has been demonstrated that performance at second level is an important consideration (the difference in CAO points between the DT299 students and the others was found to be significant) and that the pre-lecture resources for organic chemistry employed in semester 2 reduced the difference in semester test and examination marks achieved to a level that was not statistically significant among students with similar CAO points who had and had not prior chemistry knowledge.

Data have been collected to allow an analysis of the relationship between the prior chemistry knowledge of level 7 students and their Year 1 chemistry test and examination results to provide a baseline for comparison for next year when pre-lecture resources are introduced.

Qualitative analysis – by means of student attitude surveys at the beginning and end of the academic year and two focus group interviews with the level 8 students who used the pre-lecture resources – has taken place and is discussed in the following section..

Evaluation and Conclusions

Attitudes survey

The student attitude surveys conducted were comprised of 38 statements about learning chemistry including some on pre-lecture information. Some of them had been sourced from the Colorado Learning Attitudes About Science Survey (Barbera et al. 2008). Some of the main findings are presented below in Table 9.1. It can be seen that, in most cases, similar attitudes applied at the beginning and end of the semester. The first three statements relate specifically to the provision of pre-lecture information and it can be seen that there is an increase from 83% to 92% agreement with the statement that it is helpful to have had some of the terms explained in advance of a chemistry lecture. This is taken as evidence that learners found the pre-lecture approach useful. The responses in relation to a preference for using textbooks or multimedia tools are also interesting and the authors feel that the area of student textbook use merits further study.

Statement on Attitude to Learning Chemistry from Survey	Responses: Week 2, Semester 1 (57 level 8 and 79 level 7 students)	Responses: Week 11, Semester 2 (65 level 8 students)
I find that if too many new terms and concepts are introduced in one lecture, I struggle to understand	54% agree 20% neutral	54% agree 18% neutral
It is helpful to know in advance what topics each chemistry lecture will be about	90% agree 9% neutral	91% agree 5% neutral
It is helpful to have had some of the terms explained in advance of a chemistry lecture	83% agree 15% neutral	92% agree 6% neutral
It is important to know how a new chemistry topic relates to what I already know	89% agree 8% neutral	92% agree 6% neutral
I like to use multimedia tools to help me to study chemistry	58% agree 27% neutral	52% agree 32% neutral 12% disagree
I like to use textbooks to help me to study chemistry	64% agree 27% neutral	35% agree 45% neutral 22% disagree
I can access the internet easily when I need to	86% agree 8% neutral	91% agree 5% neutral 3% disagree

Table 9.1 Main findings from the attitudes survey administered at the beginning and end of the academic year

Focus groups

Two focus group interviews were carried out with the level 8 students who had used the organic chemistry pre-lecture resources towards the end of semester 2. The questions asked dealt with experiences of using the pre-lecture resources and of the learning environment for chemistry. One focus group was made up of learners with prior chemistry knowledge and the other group only included students who did not have prior knowledge. Participants were selected based on their course of study, prior knowledge, test performance and sex and each focus group had 6 participants. Some of the main outcomes from the interviews are listed in Table 9.2 below.

Area Discussed	Responses: Students with prior chemistry knowledge	Responses: Students without prior chemistry knowledge
Experience when pre-lecture resources provided	Found them very useful for topics that had not been covered at Leaving Certificate. Did not always refer to the pre-lecture material before taking the quiz for topics they were familiar with.	Were at an appropriate level and provided an introduction to a topic. The lecture was a reinforcement and they could listen more in class. Felt more confident in the lecture.
Experience when pre-lecture resources not provided	Felt less prepared for the lecture and often overwhelmed during it.	Felt unprepared and lost and did not understand new terms being used.
Is it important to associate an assessment mark with the resources?	Yes, it provides an incentive and is not very time consuming to do.	Yes, it is an incentive but all students said they would still do it if there was no mark.
Positive experiences	Gives confidence and a "feel good" factor when do well on quiz. Helpful to have terms explained in advance.	Allows active learning. Improves confidence as knowledge being built up is tracked.
Negative experiences	Some multiple choice questions on the quiz needed to be read carefully to get them correct.	Forgetting to do the pre-lecture resource and feeling lost in the lecture as a result.
Suggestions for improvements	Use bullet points more for clarity. Add audio commentary to the electronic version.	Include one animation with each resource, not just some of them. Add audio commentary to the electronic version.
Other comments	Quizzes provide evidence of understanding.	The quizzes promoted discussion among students, particularly if someone got an answer incorrect.

Table 9.2 Main findings from the focus group interviews conducted with level 8 students

As had been hoped, students reported that they felt they could listen more during lectures and were more confident about their knowledge on a topic when pre-lecture resources were used. The group who had prior chemistry knowledge did not always review the pre-lecture material when they were familiar with a topic but they were very appreciative of it when they encountered new material. All students who participated expressed a preference to have an audio commentary added to the resources.

Recommendations to the DIT

On the basis of their fellowship research, the authors would like to make the following recommendations:

1. The use of pre-lecture or pre-laboratory activities should be encouraged as an effective means of bridging the gap between those with and without prior knowledge in a subject, and as a means to improve the first year experience.
2. The Respondus software used to prepare and administer the quizzes operated within the college VLE and this made administration quite easy, and automated the compilation of marks. This considerably reduced the workload associated with this mode of continuous assessment, and continued promotion of software such as this to staff is recommended.
3. Consideration should be given to encouraging the approach employed in this project of extending and further evaluating a novel pedagogic approach developed a year previously by a colleague. We have found that it has provided a very effective means of ensuring sustainability of the two fellowship projects concerned and has promoted collegiality.
4. Statistical analysis of student performance in relation to factors such as prior subject knowledge, CAO points, programme of study and performance in Leaving Certificate mathematics can provide valuable information about first year undergraduates (and indeed subsequent years). Consideration could be given to providing incentives to staff who are interested in undertaking this work, such as small grants to allow a research assistant to be paid for a couple of days or assistance from students who are enrolled on relevant courses which feature data analysis and statistics.

Proposed Future Work

As requested by the students interviewed, audio commentaries will be added to the 10 pre-lecture resources in organic chemistry that were used this year.

The general chemistry resources developed will be implemented with level 7 students in 2012–2013 and it is also intended to modify the organic chemistry resources used with level 8 students so that they can be extended to level 7 next year.

Further analysis of the data obtained on the level 7 and level 8 cohorts of students will be performed to investigate whether performance in Leaving Certificate mathematics has a bearing on their first year chemistry results at third level.

It is also hoped to probe whether learners' metacognitive skills relate to their performance at third level. This is likely to require individual interviews with students, and student attitudes to using textbooks can also be examined.

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