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Online Support and Online Assessment for Teaching and Learning Chemistry

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Online Support and Online Assessment for Teaching and Learning Chemistry

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In this chapter, examples of innovative approaches that use educational technology to support active learning in chemistry lectures, tutorials and laboratory sessions are considered. The scope of the chapter is limited to blended learning. The strengths and weaknesses of e-learning are examined and the options available for online assessment using electronic tests and e-portfolios are discussed. In addition to the literature references provided in the chapter, several examples of good practice involving the implementation of information and communication technology for chemistry teaching in higher education are incorporated. A list of online resources for lecturers is also included.

Introduction

> *"Learning how to learn has become the most fundamental skill that an educated person needs to master, and the instrument that enables learning in almost every field is the computer."*
> *(Dr. Peshe Kauriloff, Adjunct Associate Professor of English, University of Pennsylvania, retrieved from e-Learning Centre website at www.e-learningcentre.co.uk/eclipse/Resources/quotations.htm)*

Students today use communication technology extensively. They chat online daily with their friends, they use e-mail and social networking sites and many children already have a mobile phone by the age of ten (Schüz, 2005). Young students are already accustomed to retrieving information they require rapidly and at any time using the Internet and to viewing, generating and sharing video clips on a wide range of topics using websites such as *YouTube*. In addition, they often keep weblogs or contribute to discussion boards or fora that interest them. Thus, this should make it easy and natural

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for them to use similar technologies in education such as electronic learning environments, discussion boards and chat rooms.

The aim of this chapter is to examine innovative teaching and learning methods in which learning technology is applied to facilitate learning, as well as web-based assessment for undergraduate chemistry students in both practical sessions and lectures. The scope of this chapter is limited to blended learning. Distance learning is not considered. The strengths and weaknesses of online learning are examined initially and then a brief overview of the relevant educational theories is presented. Examples of how online resources have been used to support the learning of chemistry undergraduate students in laboratory practicals and in lectures are discussed. This is followed by an examination of approaches used that involve online assessment. In addition to online multiple choice tests and quizzes, e-portfolios and online collaborative group assessment are also discussed. The online resources provided to lecturers and to students are then considered and several lists of those available appear at the end of the chapter. The chapter closes with a brief review of developing and future trends.

Blended learning

The examples discussed here involve blended learning rather than web-based learning alone. The term blended learning is usually understood to describe course delivery in which a combination of face-to-face and online teaching and learning takes place, but the “mix” of the two components can vary considerably (Williams, Bland & Christie, 2008). There are several alternative interpretations of what blended learning involves, including one that views it as a blend of different types of web-based tools and media only (Whitelock & Jelfs, 2003). In their review, Sharpe, Benfield, Roberts and Francis (2006) acknowledged that blended learning is not easy to define but they came to the conclusion that the use of the term should be continued because this lack of clarity allows teaching staff the flexibility to develop their own meaning appropriate to their context. They also suggested that academic staff feel reassured by the implication that face-to-face contact with students is preserved in a blended learning approach. The rationale that is recommended is that online learning be used to complement other methods, not replace them, and that it should only be incorporated if it enriches and enhances learning (Charlesworth & Vician, 2003).

Implementation of educational technology in higher education institutions

There is no doubt that the introduction of technology in teaching costs money. Laurillard (2002) analysed the methods of online communication used for teaching and learning in higher education and discussed their implementation. She found that the relationship between benefits and costs is complex. Laurillard (2007) later developed a modelling tool to allow developers to construct a plan on how to improve learning benefits while controlling the associated teaching costs. She determined that there are four factors that help to bring costs down: Substitution, rather than duplication of online services, greater reuse and sharing of e-learning resources, increased peer learning, and more standardised production of materials. Systems that are well-managed and mature are necessary to make these factors work and, in many countries, governments have prepared strategic plans to improve the quality of learning using technology (DfES, 2003).

Collaborative organisations such as the *SURF Foundation* in the Netherlands (www.surffoundation.nl) or *JISC* and the Higher Education Academy (www.jisc.ac.uk) in the United Kingdom play a significant role in introducing technology into higher education in their respective countries. Initiatives that have been undertaken include funding of renovation projects to develop, improve and implement e-learning, provision of support from experts and the formation of special interest groups.

Almost every higher education institution has now incorporated an online element (often referred to as e-learning) into their courses. To be able to use this technology, academic staff need to modernize their teaching and it is important that their attitude towards their teaching is as progressive as their approach towards carrying out research. Michael (2001) makes this point and recommends that, just as academics will keep up to date with and evaluate novel methods and technology in their field of research, they should also ensure that they are aware of new teaching and learning technology and methodologies.

The way in which learning technology is used for teaching and learning can vary significantly. In the United Kingdom, Sharpe et al. (2006) carried out a wide ranging review of literature and practice on the undergraduate experience of blended learning. They classified two main approaches adopted in higher education institutions. The first is the provision of additional support material online. The second, less common, one involves course redesign to promote learner communication and interaction using information and communication technology (ICT). A third approach that uses technology in education aims to bring learning closer to research practice. Research-oriented learning activities stimulate the development of independent learners (Brouwer, Byers & McDonnell, 2006; see Godehart, Lindblom-Ylänne & Finlayson in this book). In many fields in chemical research, computers are essential and applications often use data online. In addition, collaboration of research groups, learners or individuals is now often web-based (see Eilks, Markic, Bäumer & Schanze in this book). Most computer applications for research have become sufficiently user-friendly to enable them to be used by students in research-oriented learning activities to solve realistic chemistry problems. To perform research, students need access to the latest literature and this is facilitated by using electronic scientific literature resources such as *Google Scholar* (scholar.google.nl), *ISI Web of Knowledge* (apps.isiknowledge.com), *SciFinder Scholar* (www.cas.org/SCIFINDER/SCHOLAR/) and *Beilstein CrossFire* (www.beilstein.com). These resources, with the exception of *Google Scholar*, are not open access although many institutions offer these resources as a facility for their students and staff.

Evaluation of the strengths and weaknesses of e-learning

The benefits

The use of ICT can support the learning process and enhance communication. It facilitates the transformation from the classical teacher-centered process characterized by teacher-to-student communication flow, separated working forms, guided tutorials and closed experiments (Figure 1) to a flexible student-centered learning process in which the student constructs his or her knowledge using different sources (Figure 2) (Brouwer, 2006).

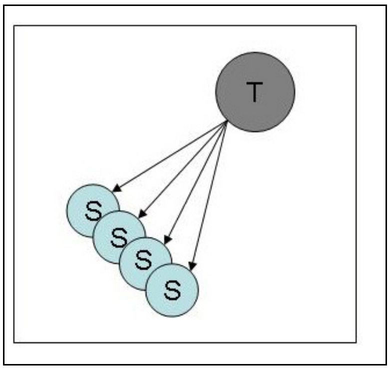

Figure 1: Teacher-centered process

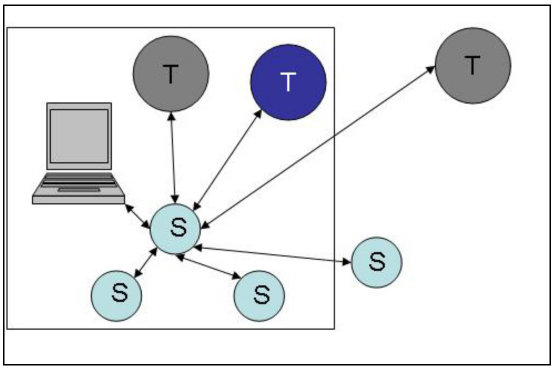

Figure 2: Student-centered process

Communication online can be synchronous (chat room) or asynchronous (discussion board). These options can accommodate situations where the students and the teachers are not in the same location and where they may or may not be online at the same time. Also, others can become involved in the educational process, e.g. lecturers from other courses and students and lecturers from other institutions or experts in the field (Figure 2). Students can readily collaborate online by working in groups sharing online space and discussion boards (see Eilks, Markic, Bäumer & Schanze in this book).

Face-to-face interaction differs significantly to online and it is important to recognize this. Gilly Salmon (2004) has developed an excellent five-stage model for e-tutors to provide a framework within which they can assist learners with this change and support them sufficiently during their initial online experiences.

Flexibility of access to online resources and communication tools is a significant benefit of web-based learning. By means of electronic learning platforms, students can access teaching materials and resources at any time and use a range of communication tools and online quizzes or tests on any networked computer. Computers can also be very useful tools for diagnosing students’ pre-knowledge. Adaptive electronic tests can be used and learners receive feedback individually so that they know where they have any knowledge gaps they need to address. A learning support to facilitate refreshing students’ pre-knowledge can also be provided within the virtual learning environment (VLE) for a particular course. This approach has helped students to get better results when studying chemistry and to improve their performance in exams (Lovatt, Finlayosn & James, 2007) or to brush up on gaps in mathematical knowledge before studying courses such as quantum chemistry (Koopman, Brouwer, Heck & Burna, 2008). Simulations can be used to develop understanding of chemical concepts in different contexts and, in inquiry-based courses computers can be used as research tools to help solve more complex and realistic problems.

Barak and Dori (2005) showed that integrating information technology (IT)-supported project-based learning into a chemistry course had a positive effect on students' learning outcomes and their level of understanding. Web-based inquiry activities in combination with the construction of 3D molecular models on a computer enhanced the learners' ability to operate on four levels of chemistry understanding: Macroscopic, microscopic, symbolic and process. Another development is the use of online resources and freeware programmes to redesign teaching laboratories so that they replicate the situation in a research laboratory. This approach produces situations that mimick real-life and can improve the development of students' problem solving skills (Cox et al., 2008; Tsai, 2007).

The Internet provides an excellent means of providing learner support and resources. However, in order to make full use of its potential, web-based learning can also be employed as a framework for learner activities, particularly collaborative group activities. An important advantage of web-based information is that it provides the opportunity to work in groups to produce and edit web materials using wikis. The wiki functionality can thus be used in education to provide a space in which students work and learn collaboratively. The additional flexibility afforded by web-based learning as well as its suitability for collaborative group learning through the use of discussion boards, chat rooms and wikis has the benefit of providing a new means of developing independent learners. Chickering and Ehrmann (1996) emphasised the benefits of using online group projects as assessment methods as they incorporate several of their seven principles of good practice in undergraduate education, including active learning, student-student interaction and the requirement for time on task. They also reported that it is often observed that learners perform to higher levels when they know that their peers will be able to view their assignments and correspondence online. Another advantage of e-learning is that it assists the development of information technology, collaborative work and communication skills which are all very important in a working environment. It is interesting to note that several studies have shown that female students benefit more from web-based learning activities than male students and that they opt more often for voluntary activities than male students (Herman et al., 2005; Botch et al., 2007),

Common problems

There are several common difficulties associated with online learning The initial induction and access stage is critical and requires careful planning and support (Salmon, 2004; Laurillard, 2002; Holmes & Gardner, 2006; Sharpe et al., 2006). Other issues include the challenge of keeping learners motivated and engaged access to networked computers, technical problems, anxiety over time management and the difficulty with developing social interaction online. There are also a number of barriers to the successful implementation of online learning that are often encountered at an institutional level such as the provision of the necessary support structures and development of a clear e-learning strategy. Thus, institutional and financial support, sufficient time allocation, appropriate professional development courses for academic staff to learn new technologies and ongoing support from experts and peers are important requirements. Holmes and Gardner (2006) emphasise that structures and resources need to be put in place to facilitate web-based learning innovations without excessive preparation and time commitments and Mason (2001) observes that ways of reducing the time demands on online tutors need to be found as ‘interaction fatigue’ can set in. The introduction of technology in education has had a significant impact on time resources, both of the student and of the lecturer (Laurillard, 2007). On one hand, technology can save a lot of the time required to evaluate students’ work. On the other hand, it diminishes the border between time and space and students expect instant feedback from their lecturers 24 hours a day.

The observation has also been made that students can find the change from traditional teaching practices difficult because they are now required to work continuously over the entire academic year. Lovatt et al. (2007) report that the first year undergraduates they studied engaged with the teaching material provided online in the weeks before exams but did not tend to engage during the rest of the semester. Related to this is the problem of the extent of part-time work that students are currently undertaking. Concannon, Flynn and Campbell (2005) identify ‘full time part time students’ as a recent phenomenon in higher education institutions. These learners are enrolled on full time courses but also spend significant amounts of their time working in part time jobs.

Problems with online learning can also arise due to a lack of permanence of the links to the resources provided. Markwell and Brooks (2008) analyzed a “link rot” phenomenon in chemistry web courses. They followed the URLs of 515 web courses. About 100 disappeared after one year and, after 78 months, only 181 were still accessible. Possible causes were also discussed by the authors. Another issue is that information online can contain errors and misinformation. This was reported in a study published in Nature (Giles, 2005), however, reliability seems to be improving as science entries in *Wikipedia* contain approximately four inaccuracies on average and entries in *Encyclopaedia Britannica* about three.

In technology-enhanced learning, special attention must be given to providing guidelines about plagiarism, especially when students are working on projects or writing reports and essays. Students can often be tempted to use the copy and paste function when reporting on the work of others. Educational software such as *Ephorus* (www.ephorus.com/higher-education) and *Turnitin* (www.turnitin.com) is available to detect plagiarism and assignments submitted using the *Blackboard* electronic learning environment can be scanned automatically for plagiarism. Cheating is also considered to be a potential problem in e-learning, however, Charlesworth, Charlesworth and Vician (2006) showed that students’ perception of the effect of using an electronic course management system on the level of cheating is not significant. In addition, clear guidelines on “netiquette” (internet etiquette) are required when students will be engaged in communicating by electronic means (Shea, 1997).

Knowledge for all

We would like to end this section by emphasising the potential of ICT to bring educational resources to every citizen of the world for the cost of an internet connection. For example, Massachusetts Institute of Technology has opened its course materials to the whole world with their *MIT Open Courseware* (ocw.mit.edu/OcwWeb/web/home/home/index.htm). This decision was made based on the argument that educational resources should be accessible according to non-proprietary, peer-to-peer, and open-source software principles (Malloy, Jensen & Regan, 2002). Sharing of material and the resultant exchange of ideas among lecturers also has an important role to play in improving the quality of teaching in higher education. Initiatives such as the *Open Educational Resources Commons* (www.oercommons.org) (Mittal, Krishnan & Altman, 2006), *MERLOT* (Multimedia Educational Recourse for Learning and On Line Teaching, www.merlot.org/merlot/index.htm), the European learning objects repository *Ariadne* (www.ariadne-eu.org), and the ECTN chemistry tests database EChemTest (www.cpe.fr/ectn-assoc/echemtest/index.htm) offer lecturers access to educational material and hopefully motivate them to share their own materials. Issues relating to intellectual property and copyrights for open access teaching material in higher education are regulated according to the *Creative Commons Licence* (creativecommons.org).

Relevant learning theories

There are a number of learning theories underpinning e-learning methods. These are cognitivism (relates to online tutor support and teaching materials), learner differences theory (multiple representations of a topic e.g. animations, text, video and audio clips, graphs) and constructivism (online learning activities, e.g. quizzes, crosswords, wiki construction, problem solving). Where online collaboration is involved, this incorporates a social constructivist approach. A brief summary of the main principles of each educational theory follows (see also Byers & Eilks, or Eilks, Markic, Bäumer & Schanze both in this book).

Cognitivism focuses on the means by which the learner processes information. Knowledge is considered to be absolute and fixed and links to existing knowledge are encouraged. The goal is to develop critical thinking and problem-solving abilities (Toohey, 1999). Information is structured and sequenced to facilitate processing and the tutor organises practice and feedback to ensure that new knowledge is assimilated. Use of learner support resources such as notes and summaries, practice problems, useful links and online tutor support reflect a contribution from the cognitivist approach. The variation in style and approach that exists among learners is the basis for the learner differences theory (Beetham, 2002). Multiple representations of learning content are required to accommodate the range of learner types (graphs, simulations, animations, text, video) and it is recommended that a number of routes (linear and networked / cross-linked) to navigate through material or an activity be provided (Chickering & Ehrmann, 1996).

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 and will construct their own interpretations of the knowledge provided to them. Thus, each individual learner will have their own perspective and experiences (Crotty, 1998). Providing learners with online activities should keep the learner motivated and encourage them to take charge of their learning. Active learning is considered necessary to the constructivist approach and so the use of online learning activities shows the influence of constructivism on course design.

The social constructivist theory of learning, which originated with Vygotsky (1962), claims that learning centres on social interaction and shared tasks in which individuals build their learning by interacting with the environment, particularly teachers and fellow students (Beetham, 2002). Collaboration on meaningful and challenging activity-based programmes promotes exploratory learning and is regarded as a highly effective means of encouraging learning (Bigge & Shermis, 2004). The advantages of this approach are that learners can capitalize on their strengths and overcome their weaknesses while working on a collaborative task. They also get the opportunity to encounter alternative methods adopted by other learners. A number of authors point out that interactive, collaborative learners can be well-supported in a web-based environment and remark that asynchronous online communication encourages significant peer interaction to take place (Roberts, 1995; McMahon, 1997; Oliver, 2001; Gagné, Wagner, Golas & Keller, 2005).

Effects of e-learning activities on students’ learning progress

Online self-directed learning to construct knowledge and skills

Among the significant benefits of online learning identified by students are the opportunity to work at a suitable pace and the accessibility afforded. Provision of a range of online learning materials, activities and self-tests with instant feedback allows learners to determine how well they understand and can apply material introduced in their lectures (Adams, Byers, Cole & Ruddick, 2003). This type of support has been found very useful for teaching chemistry to large groups of first year undergraduates, particularly those who have not studied chemistry at secondary level.

Examples of this approach include development of online self-study quizzes with instant and detailed feedback to allow first year students at Dublin Institute of Technology, Ireland, to determine how well they understand and can apply the topics they are being taught (O’Connor & McDonnell, 2005).

In order to encourage use of these quizzes, an online assessment test that used a selection of the self-study quiz questions was introduced towards the end of the academic year. Another example at Plantijn University College, Belgium, involves the provision of online courses and exercises for self-directed study and related exercises (e.g., stoichiometry problems) online. The purpose of the courses and exercises is to allow learners to fill any gaps between their secondary school science knowledge level and the initial knowledge level required for higher education. Extensive feedback is provided online to students who have attempted the exercises. In addition, staff and each student can track the activities they have undertaken and thus monitor learning progress. Based on their work at Dublin City University, Ireland, Lovatt et al. (2007) have reported that there is some evidence that first year students will only interact with quizzes and other support material if they form part of the assessment for the course. Also, they found that if quizzes are considered too difficult, then generally, if they are not assessed, they will not even be attempted. A description of the online support provided at Robert Gordon University in Scotland follows:

Online help for on-campus and off-campus students at the Robert Gordon University

Several years ago, the Robert Gordon University in Scotland developed its own VLE called the *Virtual Campus*. It provided a comprehensive infrastructure and facilitates interaction between staff and students supporting course delivery, tutoring, and discussions. The Virtual Campus was used by two distinct groups of students; full-time on-campus students and the off-campus students who study by distance and on-line learning. This latter group of students was particularly dependent on the material posted on the Virtual Campus. The university recently made a strategic decision to change their VLE to *Moodle* (www.moodle.com) and, since September 2008, the VLE is to be called *Campus Moodle* (campusmoodle.rgu.ac.uk). Course materials are posted up by module, but there are also general information modules. Material posted varies with each lecturer but, typically, not only will the lecture materials be posted up for downloading, but other support materials such as useful website addresses, computer quizzes and sample exam questions are also included. For first year students, revision materials and self-study materials are also posted to help fill in any gaps in their knowledge and understanding from the various courses they have studied prior to entering the university. It has been suggested that posting up lecture materials can result in students stopping attending the lectures, but this has not been found to be the case here and indeed the extra materials can help students to take charge of their own learning.

122 first year science students (forensic science, biomedical science and nutritional science) who all took the same introductory science module were asked to fill in a questionnaire about how they used the support materials on the Virtual Campus. 64 replies were received. 100% of these downloaded the lecture notes. When asked, however, if they downloaded the answers to tutorials or tried the mole calculation quiz the “yes” response dropped to 56% and 58% respectively showing that there is still some work to be done

to encourage students to become more independent. The responses then dropped to only 24% with regard to using the recommended text book. The drop in use of the support materials could however also be attributed to the fact that this was an introductory science module. Therefore, some of the students would be very familiar with the materials and knowledge and would not have felt the need to complete the extra work.

For the off-campus students studying the diploma in applied chemistry by distance-learning, the Virtual Campus provides a comprehensive infrastructure with the flexibility for study in the students' own time. The learning materials are accessed using the Internet. The Virtual Campus further facilitates interaction between staff and students to support the course delivery by the use of discussion fora, community groups and email. A large part of the learning experience is delivered by online tutorials or by email. In a similar way to the on-campus students, quizzes, crossword puzzles and other support materials have also been devised in addition to the main course content. Students are also directed to suitable websites. This use of the VLE is becoming more and more attractive to students wishing to study part-time whilst pursuing full-time employment.

In the first years in which they study chemistry, students are required to learn quite a lot of information. For example, to understand organic chemistry at an advanced level, it is recommended that the learner is familiar with a certain number of important reactions. Study aids such as the "Reaction Rolodex" have been developed to help students to remember important information about these essential organic reactions. It has been shown that students who used this tool responded positively to it and their performance on the reactions section in their first year organic chemistry exam was better than in the group not using it (Mahan, 2006). Koopman et al. (2008) have shown that students were better able to comprehend lectures in quantum chemistry when they had brushed up on their mathematics pre-knowledge gaps systematically using the computer algebra test tool *MapleT.A* (www.maplesoft.com/Products/MapleTA/index.aspx). The software provided instant feedback and the quantum chemistry lecturer reflected on this feedback in the lectures. The study carried out showed that good mathematical skills are essential, but were not sufficient for studying quantum chemistry as abstract thinking skills were also required. This approach, combined with interactive teaching activities implemented to improve abstract thinking, resulted in a substantial improvement in the percentage of students who passed the quantum chemistry course.

Development of information literacy skills is very important, as the ability to find relevant information quickly and efficiently is one of the key factors that can promote lifelong and self-directed learning to (Sormunen, 2006). Ambrose and Gillespie (2003) are among several authors who have made the case for integration of information literacy skills into curricula. It is recommended that during their first semester, undergraduates are introduced to library resources and are encouraged to develop library research skills to enable them to make effective use of library resources, both paper and electronic, and to evaluate their usefulness and relevance. This process can be readily supported by means of online activities and materials, such as the *Internet Chemist Tutorial* (www.vts.intute.ac.uk/he/tutorial/chemistry). These skills need to be developed on an ongoing basis and Walczak and Jackson (2007) discuss the implementation of an information literacy skills component into a third year analytical chemistry course. In addition, the analytical chemistry programme involves the use of role-play. Each student gets an opportunity to have a manager, chemist, hardware or software role in a four person group called a “company” with much of the communication among the group being carried out online.

Preventing misconceptions

Chemistry is challenging to learners because a chemist needs to think on several levels: The observational level (macro level), the molecular level (sub-micro level) and the symbolic and process level (Johnstone, 1982, see Fiorano, Markic, Reiners & Avitable in this book). This can lead to misconceptions which are often very difficult to overcome and can even prevent any further learning. Visualization of chemical structures and reactions on a molecular level is introduced to develop a deeper understanding of chemistry in learners. Computer animations, simulations and 3-D molecular modelling can be used to improve learning and understanding of chemistry, not only by students at the beginning of their study, but throughout. In addition, experts in the field now often also make use of these techniques in their research.

In the *VisChem* project, all levels of chemistry are combined and taught together using computer animations and molecular models (Tasker & Dalton, 2006, 2008). The *VisChem* learning design helps students to deal with their misconceptions in four steps: (1) explain the observation using the prior mental model, (2) recognize the failures of the prior model, (3) use computer animations to reconcile the discrepancies in the model and (4) apply the new model to a new chemical topic. This constructivist learning design makes it possible to construct better mental models however it must be noted that, by using molecular models and animations, the students can also develop different misconceptions.

Limniou, Roberts and Papdopoulis (2008) compared the effects of using computer-based 2-D chemical animations with using 3-D ones. It was found that the students who used the 3-D animations had a better understanding of molecular structures and changes that occur during a chemical reaction than those who were using the 2-D animations. In addition, an increased level of enthusiasm was noted among the students who had access to the 3-D option.

Project-based learning

Project-based learning (PBL) requires students to solve real life problems and information technology provides a very effective support for this teaching and learning method. Barak and Dori (2005) researched the effect of IT-enhanced PBL on students’ achievements and on their ability to traverse various chemistry understanding levels in three undergraduate chemistry courses. The student projects included three assignments:

Molecules in daily life, elements in the periodic table, and scientific theories. To solve these problems, students used a range of IT tools for modelling and visualization of molecular structure as well as internet resources. The qualitative and quantitative results indicated that incorporating IT-rich PBL into chemistry courses can enhance students' understanding of chemical concepts, theories and molecular structures.

Online collaboration

Slocum, Towns and Zielinski (2004) have devised a method for analyzing electronic communication by means of discussion board diagrams which show the effect the tutor/facilitator is having and identify all interactions that have occurred. Their analysis has allowed them to formulate useful guidelines for effective facilitation of online collaboration in chemistry courses. Glaser and Poole (1999) describe the development of collaborative learning communities in organic chemistry facilitated by online communication. Students worked in groups of 5 to 6 and researched a range of topics. The students were only required to format their reports so that they could later be easily published on the module website but half of the groups were sufficiently motivated to build their own websites. Peer assessment of reports by other groups was also incorporated (see also Eilks, Markic, Bäumer and Schanze in this book).

Keller and Cox (2004) developed an innovative cross-disciplinary collaboration between business and chemistry students studying a Biochemistry module that involved a significant amount of online communication. The chemistry students investigated the type of research and product lines for a number of companies who had a mission statement that mentioned proteomics. Business students, who were enrolled on an online course, then analyzed the business model, marketing plan and industry growth potential of these companies and 1000 dollars of virtual money was invested in a company. Towns, Sauder, Whisnant and Zielinski (2001) have developed a number of online physical chemistry modules that are used across several American third level institutions and allow collaboration between their students.

Activation of students during lectures and tutorials

In a lecture environment, incorporation of online methods can be achieved by using simulations, animations and computer-generated molecular models to demonstrate and explain difficult concepts. Some lecturers opt to develop this type of material themselves using the scientific software employed for their own research but it is also possible to search for this material online in a range of repositories (see the lists of resources at the end of this chapter).

A good explanation by the lecturer is not enough to achieve deep learning by students. The learners need to be actively involved (Stanley & Porter, 2002). Plenary or group discussions and an exchange of opinion with a neighbouring student as well as asking questions are common methods employed to make lectures active and interactive. Electronic voting systems (also often called student response systems, personal response systems, audience response systems, audience paced feedback, classroom communication systems, voting-machines, zappers or clickers) have been used since the early 1960s. Initially, these systems were built in but nowadays the personal response systems are wireless and portable and are relatively inexpensive. In some cases, web-based public response systems are used which involve students using their mobile phones to vote (Prensky, 2005). MacArthur and Jones (2008) have published a comprehensive review of the implementation of clickers in third level chemistry courses in which they report that students have invariably been found to react positively to use of this technology and that, in cases where some type of student collaboration was also incorporated, measured improvement in student learning was observed. Niyadurupola and Read (2008) reported similar findings when they piloted the use of clickers in two English universities.

A teaching method called peer-instruction was introduced very successfully in physics courses for new undergraduates at Harvard University and has been extended to a number of other colleges (Mazur, 1997). In his introductory physics lectures, Mazur asked each student to provide a response to multiple choice questions using a clicker. Students were then required to discuss their chosen answer with their neighbours and then vote again. This approach was shown to dramatically increase pre-to-post test gains (Crouch & Mazur, 2001). It should be noted that careful selection of questions is an important factor in implementing this approach successfully. Wieman and Perkins (2005) also discuss how educational technology can be used very effectively to improve learning by physics students and, in particular, the role of clickers and online interactive simulations.

Christie (2008) has used commercially available technology (Mimio hardware and software; www.mimio.com) to capture pen strokes made on a white board during a lecture and save them to video files that can be played by students anywhere. He has used this system to allow conventional organic reaction mechanisms to be stored, played, paused and rewound as necessary. Since the diagrams are hand-drawn, there is no learning curve for lecturers that involves complex computer software and, because the pen-strokes are recorded in real time, the diagram evolves on the computer screen as it did on the whiteboard in the lecture.

Enhancing learning during lab sessions

There is no need to emphasize how important it is for chemistry students to obtain effective laboratory experience (see Bennett, Seery and Soevegjarto-Wibers in this book). The quality of the learning process can be enhanced by ICT during pre-lab or post-lab activities. For example, computer simulations can support learning about particular experimental techniques and may, in certain cases, replace working in the laboratory if there are safety or ethical reasons (e.g., live animal experiments) which preclude this (Wang, 2001).

Pre-lab activities have been shown to be important in improving learning in chemistry across all levels. For example, in a simple operation such as extraction, many students find it difficult to visualize what is happening at a molecular level. An interactive simulation of this process used in a pre-lab session has helped students to understand it better at the macroscopic and at the molecular level (Supasorn, Suits, Jones & Vibuljanc, 2008). Interactive multimedia exercises (IMMEX), were developed at the University of California Los Angeles medical school. The problems can be used as a pre-lab session to enable learners to become acquainted with a particular technique, or as an assessment tool. The IMMEX problems are based on real life situations which students might encounter involving organic separations and TLC, qualitative organic analysis, and spectroscopic analysis. The online software used makes it possible to interpret students' problem solving strategies (Cox et al., 2008).

Chittleborough, Mocerino and Treagust (2007) studied the impact of online pre-laboratory exercises and resources on students' learning in an introductory chemistry course. The online pre-laboratory exercises were designed to make students identify the aim of the weekly experiments. Pictures and diagrams of unfamiliar equipment were provided to introduce the methods and the procedures and students could use a range of resources (online and the manual) to solve the problems they were asked to complete. Immediate electronic feedback on the student's solution was provided and multiple attempts were allowed. The results show that the majority of students appreciated the flexibility in time and place provided by this system and most of the students stated that they felt that this system prepared them better for the laboratory activities than the classical approach previously used. Burewicz and Miranowicz (2006) report that students who used interactive multimedia in their pre-lab sessions completed the experiments in a shorter time and with less problems than the students who used the printed or video instruction.

Josephsen and Kosminska Kristensen (2006) gave their students on an introductory inorganic chemistry lab course a computer simulation of the laboratory assignment in addition to the laboratory assignment and a written problem. In all three types of learning resources, the information was given at the macroscopic level only. The students had to transform this information into chemical conclusions. The computer simulation used (*SimuLab*) is also a cognitive tool and it was found to develop the learners' experimental and analytical skills and to improve their interpretation of experimental results. It facilitated students' knowledge construction by engaging them in cognitive activities which would not be possible during the laboratory session because of their cognitive load. It has been shown that lower cognitive processes in the lab are not performed automatically by novices and, for this reason, they cannot use their higher cognitive skills optimally during the early stages in the lab (Sweller, 1988; Sweller & Chandler, 1991).

Educational technology has also been applied to improve writing skills in larger groups of students. *Calibrated Peer Review* (CPR, cpr.molsci.ucla.edu) software is a browser-based tool which enables academic staff to create writing assignments that incorporate a requirement for students to review examples (calibration assignments) and, after they submit their work, review assignments submitted by their peers. The tool is universal as the lecturer determines the structure of the assignment using different templates with criteria such as learning goals and can calibrate source materials, questions, answers and examples. Margerum, Gulsrud, Manlapez, Rebong and Love (2007) used the CPR tool in a large introductory chemistry lab course for pre-lab and post-lab writing assignments. They implemented a series of CPR assignments aimed at improving technical reading and writing and found that students responded that the "writing to learn" approach adopted was achieving its aims and, in general, they were engaged and motivated by this teaching method. In addition, it is reported that the students who worked with CPR could better apply their knowledge in the following year compared to students who did not complete these writing assignments. Morris (2007) also reports an improvement in learning as a result of using online self and peer-assessment tools in an introductory chemistry course.

Limniou, Papadopoulos, Giannkoudakis, Roberts and Otto (2007) discuss the introduction of an interactive viscosity simulator into pre-laboratory sessions. It was shown that the students who were allowed to use the simulator in advance found that the approach was useful, that they had a better grasp of the underlying theory and that they were more confident during the laboratory session. The incorporation of an interactive UV-Vis spectrophotometer simulator into a course on chemical instrumentation is described by Limniou, Papadopoulos and Roberts (2007). Students were asked to share measurements, observations and conclusions from their virtual experiments on the simulator by communicating online. It was found that the students valued that opportunity to collaborate with their colleagues and that they felt more confident about operating a real instrument and had a better understanding of the function and technical principles of a UV-Vis spectrophotometer than the control group of students studied.

Online assessment

It is important to ensure that both online assessment and "classical" assessments fit the didactic structure and learning objectives of the course in which they are used (Biggs, 2003). When online assessment is mentioned, we often think only of multiple choice tests. This type of assessment can be very useful for evaluating students' knowledge or pre-knowledge, particularly in the early stages of a chemistry degree. Third level institutions use electronic tests in a range of ways such as self-study quizzes, diagnostic tests or summative assessments. A range of software tools are available for designing online quizzes. Some are available free of charge, such as *Hot Potatoes* provided by the University of Victoria (hotpot.uvic.ca) and others, such as *Questionmark Perception* and *Respondus* are available commercially. In addition, most of the institutional electronic learning platforms (*Blackboard, Moodle and Sakai*) offer online assessment tools.

However, electronic tools can deliver much more than multiple choice tests and it is possible to assess students' knowledge across a range of cognitive levels. Lecturers can set online assignments that require students to submit their work to be reviewed or peer-reviewed online. This approach was discussed at the end of the previous section on enhancing learning during lab sessions in relation to pre- and post-lab writing assignments (Margerum et al., 2007) In addition, for competence-oriented modules or programmes, electronic portfolios can be used to assess students.

There are many benefits to online assessment, which include;

- Flexibility of time and place.
- After an electronic test is submitted, instant results and tailored feedback can be provided.
- Improved chance for personal development due to automatic feedback and/or online feedback from teachers and peers.
- Time savings on assessing students' work for academic staff.
- Sharing of complete student assessment results by all lecturers on a course.
- Sharing of approved tests and test items among colleagues.
- Statistical analysis of results provides information that facilitates improvement of test questions and of the course as a whole.

There are also some disadvantages:

- Initial development of online test assignments takes more time than for paper-based exams.
- Cheating by students taking tests at locations outside the college can be difficult to prevent.
- Sharing of tests and test items among lecturers who use different operating systems and/or different learning platforms is not possible if the test tools do not correspond to the same technical standards.

Effective learning support for first year undergraduates

The online self-study quizzes described in the previous section on online self-directed learning to construct knowledge and skills are often one of a series of measures implemented to support first year undergraduate chemistry students and to scaffold their learning. Lovatt et al. (2007) describe how a VLE was used in conjunction with a drop-in science clinic to provide additional learning support to first year students. Several other authors already mentioned have described similar initiatives (O'Connor & McDonnell, 2005, Charlesworth & Vician, 2003) in which a coordinated approach is undertaken that involves online support, quizzes and/or assessment as a central feature. It has been shown that students appreciate the flexibility and easy access to learning materials and that this approach results in an improvement in their confidence in relation to the subject. In addition, an improvement in exam success rates was observed when a VLE and several other changes in teaching methods were introduced in Dublin Institute of Technology, Ireland (McDonnell & O'Connor, 2005).

A recent example of an approach to improving retention and exam success rates that made use of the technology available while coping with a reduction in teaching staff resources was implemented in the University of Dundee, United Kingdom (Morris, 2007). *Questionmark Perception* tests were used to provide formative feedback and unlimited attempts were allowed. A *Blackboard* VLE was made available and the discussion board and e-mail, online group work tools and test exercise self and peer assessment tools were utilized. In-class tests using personal response systems (PRS or clickers) were also introduced and, for certain topics, just an introductory lecture was provided and this was followed by self-directed study supported online and assessed using the clickers and an online assessment. This new approach has shown a significant increase in exam pass rates and in student satisfaction.

Bunce, Van den Plas and Havanki (2006) report on the impact on student achievement of using electronic student response systems (SRS or clickers) to deliver tests to pairs of chemistry students in class compared to that of daily online quizzes delivered outside of class using a VLE. Both systems provide immediate feedback but the VLE quizzes were available for review coming up to end of semester exams while the clicker questions were not and this use of the WebCT quizzes to reflect on and review learning was found to improve student achievement. These results showed also that the way in which lecturers use clickers has a large effect on the learning success of students.

In a situation where students need to remediate their knowledge gaps to start a new programme or to follow the next course, it is very convenient to use an online preparatory course. Botch et al. (2007) described their application of *ChemPrep*, a stand-alone short course which helps students to fill the gaps in knowledge needed to begin to study general chemistry. The students who worked with *ChemPrep* were found to perform much better on the General Chemistry course than those who did not. However, use of *ChemPrep* was voluntary and it was found that it was the stronger and more motivated students who opted to do so. It is often difficult to reach less motivated and weaker students when using online applications. However, an example in which this problem was tackled is provided by Koopman et al. (2008) in relation to the first year quantum chemistry course at the University of Amsterdam, The Netherlands, as students were only allowed to sit the final exam in this course if they had completed all of the *MapleT.A.* electronic mathematics pre-knowledge tests (see above). The students could sit these electronic tests as often as they wanted and, on each attempt, a different test was generated. Instant feedback was provided and the lecturer discussed the problems during tutorials. There was no minimum electronic test result required in order to be allowed to sit the quantum chemistry exam, but it was specified that no student could submit blank or nonsensical answers in the online tests.

Online support for first year undergraduates has recently been successfully implemented at Genoa University, Italy, for a group of 300 students undertaking an inorganic chemistry module (Cardinale, 2008). As is often the case, these students have a diverse range of previous knowledge and a series of online exercises allowing them to practice stoichiometry and chemical reactions was provided which were supplemented by several face-to-face tutorials. Completion of these exercises was not compulsory but students were required to complete the other online component, a pre-lab online activity incorporating an explanatory video produced in both DVD and streaming formats using *Studio Pro 1.02* and *Cleaner 5.1* with *QuickTime 5.1* software respectively. This development is part of the web-enhanced learning project in collaboration with the CNR-ITD, an Italian research group which examines educational innovation brought about through the use of ICT.

EChemTest

The EChemTest is a project undertaken by the European Chemistry Thematic Network (ECTN, ectn-assoc.cpe.fr/echemtest/). The project involved identification of common core content in chemistry first cycle (bachelor) courses in all EU member states in physical chemistry, organic chemistry, inorganic chemistry, biological chemistry and analytical chemistry followed by the design of computer-based tests which are available in many languages to evaluate competence in these areas. Tests have also been designed to evaluate competence in general chemistry at two levels - a level equivalent to that of a person at the end of compulsory education (level 1, generally at 16 years of age) and a level equivalent to that of a student about to commence a third level course in chemistry (level 2, generally 18 years old). Students can attend a testing centre to take the test in their chosen areas and receive a certificate on successful completion. A typical EChemTest has thirty questions; 15 easy, 10 intermediate and 5 difficult. Demonstration tests can be accessed from the EChemTest website to allow students to practice. These demonstration tests can also be used as a teaching resource by academic staff. Tests at masters level are being developed and when these tests are completed, they could be used to test PhD students (see also Laganà et al. in this book).

Physical sciences question bank

This resource has been developed by the Physical Sciences Centre in the Higher Education Academy in the United Kingdom. The *Question Bank* (www.heacademy.ac.uk/physsci/home/projects/jisc_del/questionbank) is searchable according to topic, keywords, difficulty and pedagogic style. Selected questions can be downloaded in a form that can be immediately imported into a VLE or assessment tool. At present, *WebCT, Blackboard, Moodle, StoMP and Questionmark Perception* are supported. In addition, the questions can be downloaded into *Powerpoint* for use with clickers (Bacon, 2008). Many of the questions available have feedback incorporated. All users are encouraged to contact the Physical Sciences Centre with questions that they are willing to share.

Diagnostic tests

Online diagnostic tests have many applications. They can be used to advise incoming students of the probability of their success in higher education chemistry courses (Legg, Legg & Greenbowe, 2001) and are often also used to identify and address common misconceptions that students encounter and to evaluate the impact of a change in teaching method on students' understanding (Tan, Goh, Chia & Treagust, 2002). In addition, as discussed previously, they can allow students to identify areas where they have knowledge gaps that need to be addressed (Koopman et al., 2008).

Collaborative group assessment

The suitability of online learning for use in collaborative group activities has already been discussed and examples of activities that involve online collaboration were provided. Assessment of this collaborative group work often incorporates online peer review and grades are usually criterion referenced (Glaser & Poole, 1999). Self and peer assessment of a students' contribution to the group are also often used (Hinde & Kovac, 2001; Towns et al., 2001). These assessments may be circulated electronically or can be paper-based. The facility to view the history of all revisions of a wiki page prepared by students allows teaching staff to track the contributions made by each student and makes this aspect of assessment of collaborative assignments considerably easier.

e-Portfolios

An e-portfolio can be defined as "*an archive of material, relating to an individual, held in a digital format*" (Madden, 2008). e-Portfolio software provides an electronic content management system that can be used by an individual to collect, reflect on, select and present learning outcomes as well as other professional achievements (Jafari, 2004). The content can include podcasts, emails, discussion threads, blogs, written work, and journals. In some higher education institutions, customisable e-portfolios tools have now been implemented across the entire college (Lambert & Corrin, 2007). Jafari (2004) has examined the attributes needed for a successful e-portfolio system in higher education and they include ease of use, lifelong support and interoperability. He advises that it has been found to reduce confusion over what is expected if the main purpose of the e-portfolio is included in the name (*e.g.* student learning e-portfolio, career e-portfolio). Herman and Kirkup (2008) discuss a case study in which a set of structured and guided online activities were used to good effect to develop an e-portfolio on a course for women returning to employment in the science, engineering and technology (SET) sector after a break. A description of the e-portfolio system used with chemistry students in the University of Amsterdam follows:

e-Portfolios to support development of academic skills

During the three years of the chemistry bachelor degree at the University of Amsterdam, The Netherlands, special attention is paid to the development of academic competences within the compulsory modules (also called framework courses). The competences are developed to an increasing level as the students progress through their degree (Figure 3).

In 2003, in order to make the students more aware of their academic development, an electronic portfolio system was implemented which made it possible for them to collect evidence material, to reflect on the skills development process and to get feedback online. For example, within the writing skills line in first year, the students reflect on keeping a laboratory notebook during one of their lab courses and they relate this to the quality of their report on the experiments. In second year, the portfolio assignment is about writing a report on a short research project and in third year, when they have written their bachelor research thesis, they reflect on the whole process and prepare a development plan for the future. The students get feedback from the lecturers and, in some assignments, from their peers also.

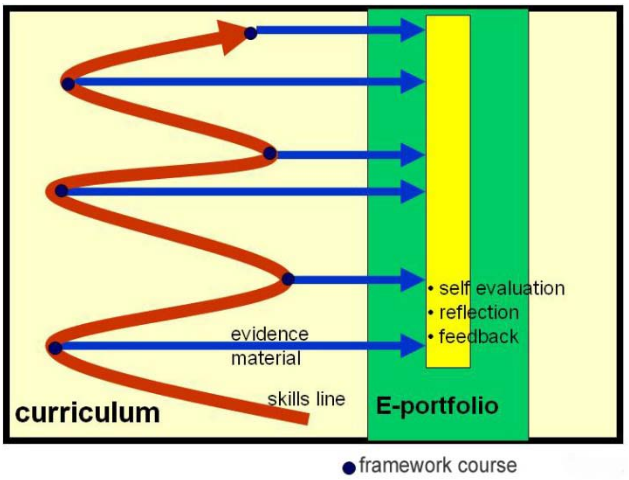

Figure 3: Skills development approach for the chemistry bachelor degree at the University of Amsterdam

In 2007, an e-portfolio matrix was introduced and this integrated reflection on development of skills with the content of the framework chemistry courses. In the cells of the matrix, students archive the evidence material about their level of academic skills and reflect on the learning process. Having the facility to look back on previous reflective assignments in their electronic portfolio allows students to recognize more readily the improvements they have made and to ascertain the areas where they still need to improve. The students can also use the matrix for material about the non-compulsory courses or extracurricular activities which they find important for their academic development. In this way, the matrix represents a mirror of their profile as a professional scientist.

The e-portfolio tool that the University of Amsterdam uses is called OSP (Open Source Portfolio) and was developed by *Sakai*. *Sakai* is a worldwide community of academic institutions and the software they develop is open access and open source. More information about the *Sakai* project can be accessed online at: sakaiproject.org/portal

Training and support for academic staff

Earlier in the chapter, the importance of academic staff maintaining an awareness of new developments in teaching methods was discussed (see also Yates & Maciejowska in this book), as was the necessity for effective online tutoring, particularly in the early stages of a course that has an online component. Both of these issues are impacted on by the extent to which adequate training of academic staff is provided so that they have developed the skills to interact effectively with learners online. Munro and Walsh (2005) discuss the development and delivery of an online tutoring course for tutors on distance education programmes. They make the point that, because web-based tutoring is a recent development, many academic staff did not experience it themselves as students and this means that they tend to feel uncomfortable about this teaching method. In order to overcome this problem, they applied the approach recommended by Salmon (2004) which is that experiencing being a student in an online environment is the most effective way to acquire the skills required to manage and facilitate online synchronous and asynchronous communication. Cunningham, McDonnell, McIntiyre and McKenna (2008) provide a detailed case study of a course of this type which is run for academic staff in Dublin Institution of Technology, Ireland. They also comment on the barriers that are often encountered at an institutional level which include lack of provision of the necessary support structures and no clear e-learning strategy.

Donnelly and O'Rourke (2007) warn of the danger that adoption of web-based learning can be undertaken in a superficial way by third level institutions if the metric used is the quantity instead of the quality of the learning. Thus, if it is perceived that information repository and course management aspects are all that are involved in online learning, then there is little incentive to develop interactive activities and assessments (individual and/or collaborative). Donnelly and O'Rourke also emphasise the need for professional development of academic staff in the area of e-learning coupled with ongoing support from experts and peers. Butler and Sellbom (2002) report that there are three main barriers to adoption of internet and web technology that they identified. They are a lack of financial support, lack of institutional support and a lack of time to learn new technologies.

The role of virtual learning environments in chemistry education

Virtual Learning Environments (VLEs), also referred to as electronic learning platforms, electronic learning environments or course management systems, are now in use in practically every European higher level institution to support flexible learning (see Laganà et al. in this book). They are software tools that provide a framework within which students can access teaching materials, resources and tests and use different communication tools at any time using a networked computer. They also facilitate course management by providing academic staff with the means to communicate assessment criteria and deadlines and other information to groups of students. Most of the innovative e-learning approaches that we describe are supported within the framework of a VLE. Some institutions use open source software such as *Moodle* to develop VLEs while others use a commercially available alternative such as *Blackboard*, *WebCT* or *Sakai* and some use customized systems that were developed in-house.

The extent to which a VLE is used as a teaching tool varies widely. In some institutions, the main functions it serves are for course management and the communication tools are used only by staff to communicate course information to the students. In others, the assessment and learning support tools available are used and, in some, students undertake online collaborative assignments and use asynchronous and synchronous communication tools. Ball et al. (2007) report that there is a great deal of anecdotal evidence claiming that use of a VLE can improve student performance and decrease failure rates.

Several authors have discussed the use of VLEs in higher education Chemistry education. Chin (2003) has produced guidelines for using VLEs in the physical sciences. Charlesworth and Vician (2003) described their introduction of a *WebCT* VLE to attempt to improve motivation and learning on a first year chemistry programme. Students appreciated the flexibility that the system allowed and, as a result of the online tests and tutor communication tools introduced, they reported having less anxiety about exams and improved confidence and perceived learning.

Lovatt et al. (2007) examined the interaction of first year undergraduates with the Moodle VLE available to them. The VLE provided self-test quizzes, lecture notes, tutorial questions, links to relevant websites and discussion fora. Students reported that they liked the accessibility and ease of use of the VLE. It was found that the learners who accessed resources (mainly self-test quizzes and notes) performed better in the summative exam than those who did not and this was interpreted to show that students who were motivated to use all available resources did better in their examination. The authors intend to implement online continuous assessment to provide additional motivation for accessing and practicing the online quizzes. Williams et al. (2008) report using a blended learning approach to teaching inorganic chemistry. Study packs were prepared based on lecture notes and included learning activities. Paper copies were made available and they were also accessible on the Blackboard VLE, as was a formative online assessment quiz for each study pack. Evaluation showed that student achievement and satisfaction increased and the authors were of the opinion that this was attributable in some part to the variety and extra support provided by blended learning.

Resources for lecturers

A great deal of material useful to teaching and learning is available online to lecturers. Many chemistry textbooks have an accompanying website which often allows lecturers to download the schemes published in the book as well as *PowerPoint* presentations that relate to the material in the book and sample answers to questions. Many publishers offer a *Blackboard* cartridge which can be opened as a *Blackboard* course site and adapted by the lecturer. Lecturers are usually required to register with the publisher to access these resources. In addition, online material such as 3D animations and simulations and electronic tests is frequently provided for students.

At the end of this chapter, we list some of the useful free resources available online at present. However, the rate of development is such that many links on this list may well become obsolete within a relatively short time as improved resources become available. Where possible, the name of the organization providing the resources and their main webpage has also been provided as it is hoped that this approach will prolong the usefulness of the list.

Emerging and future developments

Some of the relevant emerging and future trends in online learning in higher education will now be examined briefly. Online roleplay is a teaching and learning method that has been applied in a number of disciplines to date. This approach allows learners to become aware of multiple perspectives surrounding an issue and has recently been used to teach the concept of sustainability to engineering students (Maier, Baron & McLaughlan, 2007).

An emerging trend of particular interest and relevance is online problem-based learning (PBL). There have been a number of recent developments in this area. Savin-Baden (2007) emphasises that the aim of online PBL is to develop and supplement what has already been achieved rather than replace it. Another development is podcasting. Campbell (2005) explains that this approach essentially involves making audio files available to download. Learners have reported that audio file contributions were much more memorable than written discussion threads posted and facilitated a humanisation of the interaction. Holmes and Gardner (2006) have remarked on the potential benefits of recording feedback while assessing work and posting the audio file to the student immediately afterwards. However, they identify that there are problems associated with this rapid feedback approach if comments are made that have not been considered fully.

Mobile learning or m-learning is another emerging trend. At present, many institutions have a texting software package to keep students up to date with announcements such as exam deadlines and cancelled lectures and Conole, Dillon, Dart and Darby (2006) have found that students use mobile phones extensively to communicate with peers and tutors. Sharples (2007) has described the *MyArtSpace* project, in which multimedia mobile phones were supplied to second level students when they arrived at a museum. They were given several tasks to perform that required them to interact with the exhibits. These included taking photographs and video clips and collecting other relevant material which they then edited back at their schools to produce an online gallery. It was found that the students spent significantly more time interacting with the exhibits and gathering information when this approach was used compared to the traditional visit format.

Greenbowe (2008) has recently proposed that a new publication to communicate the best practices for teaching chemistry be designed and developed. He suggested that magazines that teach people to learn to play the guitar be used as a model. The new publication would include “master” teachers explaining chemistry education techniques and current technologies (an associated DVD and website) would be used to ensure effective and timely dissemination.

Conclusion

The extent to which web-based technology can be used to support and assess learning in Chemistry at third level has been explored in this chapter. A very broad range of applications have been discussed, including learning activities such as simulations of laboratory equipment, 3-D animations for visualization at a molecular level and cross-disciplinary online collaboration to research which biotechnology company has best potential for attracting investment. The variety of online assessment methods examined included peer review, pre-knowledge and knowledge testing with instant feedback and e-portfolios.

The approach used has been to provide references to and descriptions of good practice in this area as well as links to useful resources within the chapter. It is hoped that this will facilitate adoption of any suitable learning and teaching strategies discussed.

List of resources

Assessment tools

- EChemTest website: www.echemtest.com
- Eclipse crossword software: www.eclipsecrossword.com/
- Hot Potatoes assessment software: website with free download hotpot.uvic.ca/
- PBworks software (formerly Pbwiki, allows generation of wikis accessible only to specified group members): PBworks.com/
- Physical Sciences Question Bank:
- www.heacademy.ac.uk/physsci/home/projects/jisc_del/questionbank

Chemistry drawing and modelling software

- ChemSketch: www.acdlabs.com/download
- SymyxDraw (formerly IsisDraw): www.symyx.com/downloads/index.jsp

Educational resources for lecturers (can be also used by students)

- Higher Education Academy Physical Sciences Centre: www.heacademy.ac.uk/physsci/home
- Higher Education Academy: www.heacademy.ac.uk/
- Intute Chemistry Gateway: www.intute.ac.uk/sciences/chemistry/
- MERLOT (Multimedia Educational Resource for Learning and Online Teaching): www.merlot.org/merlot/index.htm
- Chemistry: chemistry.merlot.org/
- List of learning materials for different chemistry subjects: chemistry.merlot.org/materials.html
- Mind Map Generation Software: www.bubbl.us/
- MIT Open courseware: Chemistry: ocw.mit.edu/OcwWeb/Chemistry/index.htm
- Open educational resources commons: www.oercommons.org/
- Protein Explorer (macromolecular visualisation database): www.umass.edu/microbio/chime/pe_beta/pe/protexpl/
- Royal Society of Chemistry Learnnet: www.rsc.org/education/teachers/learnnet/about-learnnet.htm
- Royal Society of Chemistry: www.rsc.org/

Specific video resources and taped experiments

- Chemistry animations and movies on the world wide web: www.klte.hu/~lenteg/animate.html
- JCE Digi Demos: www.jce.divched.org/JCEDLib/DigiDemos/about.html
- Laboratory techniques. digital lab techniques meanual (MIT Open courseware): ocw.mit.edu/ans7870/resources/chemvideo/index.htm (it can be used as a teaching resource but primarily this is a student resource)
- Organic chemistry demonstration experiments on video chemistry Visualized: www.uniregensburg.de/Fakultaeten/nat_Fak_IV/Organische_Chemie/Didaktik/Keusch/D-Video-e.htm
- Science-tube.com: www.science-tube.com/, a translation of the German site www.netexperimente.de
- YouTube: nl.youtube.com, uk.youtube.com , de.youtube.com

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