Report from ECTN Working group Developing Independent Learners in Chemistry

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The working group on Developing Independent Learners in Chemistry held its first meeting in Madrid on March 24-26, 2006. The meeting was well attended. A second open meeting was held at the ECTN Plenary Meeting in Vienna on April 19, 2006.

Contents

1. Aims of the group

The past decade has seen a considerable expansion in Higher Education as we move from an elitist approach to the mass education system needed to support a knowledge-based economy. Expansion has however been accompanied by a decrease in both unit funding and staff to student ratios. This has led to claims that students must start to take more responsibility for their own learning. Many students, however, having been spoon fed throughout secondary education, currently arrive at university both unwilling and apparently unable to plan and control their own learning. If, in future, students will be expected to take more responsibility for their own learning, we must surely help them to make the difficult transition to becoming independent learners. Although university lecturers will have made the transition for themselves it is by no means clear exactly how this was achieved; certainly not by surface learning to try to satisfy assessment criteria. Students must be encouraged to identify their learning weaknesses and to confront rather than try to avoid them. This 'Thematic Network' seeks to cooperate to examine the impact of a number of approaches, including peer group work, problem based learning, mentoring, the use of information sources including newspapers, metacognition, reflective diaries, experiential learning, concept maps and ICT (Information and Communication Technology) to help students to take responsibility for their own learning and hence to become self-directed learners.

2. Introduction: *Kissing Frogs!*

Widening access in search of the knowledge based economy envisaged by the 'Lisbon Agenda' is resulting in less time being available to be spent on individual students by university lecturers. The challenge facing universities is how to maintain standards while reducing contact hours. This can surely only be achieved if students start to take more responsibility for their own learning.

Such independent learning will involve far more than mere control of the time and place where an externally imposed programme is slavishly followed. It will surely also be necessary for the independent learner to exercise control in deciding what needs to be learned to achieve required goals, how to go about this learning and to continue to reflect on learning progress. To date, little effort has been made by universities to promote such an approach though few in academia or industry would argue that it wasn't a highly desirable outcome.

Teaching at post secondary level originally developed as an effective way to pass on information, knowledge and skills from those with them to others likely to want or need them. The system that developed was very much a mentor-apprentice culture, with the mentor identifying appropriate facts, skills and activities to be mastered before the apprentice could be considered fit to perform independently. The mentor decided what was to be learned, how it was to be learned and how learning was to be assessed. The process was therefore teacher controlled and little opportunity or encouragement existed, and we suspect still exists, for independence on the part of the learner. Assessment typically focused on what the apprentice knew rather than what he or she could do with this knowledge.

While the old mentor-apprentice model might have been justified in universities in the past it surely depended on both highly motivated students and a high level of interaction between the students and their teachers. Recent moves to widen access to higher education have been accompanied by increasing student to staff ratios and a corresponding reduction in direct contact hours in many cases. This has led many to suggest that students must start to accept more responsibility for their own learning. Unfortunately, having been spoon fed throughout secondary education, contemporary undergraduates arrive at university probably unable and definitely unwilling to do just that. The vast majority of undergraduates currently accept little responsibility for their own learning and expect their teachers to tell them exactly what they should learn. Students often turn to past examination papers, 'the hidden curriculum' to decide what it is important to learn. While such an approach may prove helpful in passing exams, the resulting learning outcomes frequently show little resemblance to either the accepted curriculum or the aims of the teacher. While students must clearly start to accept more responsibility for their own learning merely telling them to do this is likely to achieve little. We must surely help them to become independent learners. Indeed given that retention is currently a major problem in many chemistry courses there is clearly a need to 'scaffold' new students while their confidence builds if drop out rates are not to increase even further. This suggests that we should concentrate our limited resources in helping students to become more independent in the early part of their course. As the course proceeds, confidence and independence should gradually develop and progressively less resources will be needed.

Students may well need to accept more responsibility for their own learning as we seek to widen participation in higher education with limited resources. There are clearly however many other advantages to becoming an independent learner. It is surely desirable and often essential in the world of work for individuals to reflect on their short comings and to initiate steps to overcome them if their careers are to develop. The widening of access to Higher Education has seen entry to many courses, including Chemistry, become much more heterogeneous in terms of both prior knowledge and achievements and future aspirations. Therefore in future individual students may well need to decide how best to allocate their time and effort as they seek to master the different parts of their course. Diversity is also likely to rise with increasing student mobility across Europe, as envisaged in the 'Bologna Agreement'. Finally there is little doubt that independence is both motivating and empowering, building confidence and ambition and encouraging further studies. Today, the importance of 'life long learning' and 'continuing professional development' are widely recognised. Such concepts are surely based on the premise that individuals will start to identify gaps in their own learning and take steps to rectify such gaps. The majority of students enrolled on primary degrees today however continue to assume an extremely passive role concerning their learning and expect to be told exactly what they need to do to succeed.

While there are few truly independent learners in primary degree courses there is little doubt that many graduates move on to become independent learners. Such independence is clearly essential to success in many areas of work and to promoting continuing professional development. All of us for example have become independent learners taking responsibility for our own learning, though it is difficult to recall exactly how this came about. The research PhD is surely a model that encourages and develops such independence and it seems likely that it was here that many of us moved from a teacher dependent, through a teacher supported, to an independent approach to our learning.

How can we as teachers then help to promote the metamorphosis of our passive, dependent students to the active and independent learners that we seek? Metamorphosis would appear to be a useful metaphor. The avaricious caterpillar gives rise to the lethargic chrysalis that in turn develops into a butterfly; spreading its wings to set out to investigate the world. Looking at ourselves we find the curious, wide-eyed toddler, surely a prototype for an independent learner, instead giving way throughout much of formal education to the passive student, who needs to be helped to develop into an independent learner. Similarly, the hyperactive tadpole metamorphoses into a lazy, unattractive frog. Yet as the Brothers Grimm discovered, some two hundred years ago, even the unattractive frog can be turned into a handsome prince, but only under very exacting conditions. No princess, however beautiful, will achieve anything by scolding or brutalising. Only through tender loving care can success be achieved. The conditions to convert passive students into independent learners are likely to be every bit as exacting.

Metamorphosis is of course a somewhat limited model for the onset of independent learning. Experience suggests that not only is the change to an independent learner gradual but, under inappropriate learning conditions, we are likely to slip back into dependency. It is less clear however whether we can get there by appropriate development of contemporary teaching approaches (evolution) or whether root and branch changes to our teaching methods (revolution) will be needed.

Independent learning is likely to be promoted where students are intrinsically motivated to study open-ended problems and are permitted the time to assimilate new knowledge in a meaningful way. Students must be permitted time to reflect on their learning, encouraged to identify weaknesses and then supported while they seek to confront and overcome them. Helping students to identify areas where they lack confidence will surely be a good start so long as they can be encouraged to persevere rather than simply allowed to ignore such problems. Assessment is a problem with all aspects of learning. If independent learning is to be encouraged it must be recognised and rewarded through the assessment process.

Inquiry and problem based learning employing open ended projects as in the research PhD are non-traditional approaches that seem likely to promote the move to more independent learning; there is generally little alternative. However this may come at a price as control of the curriculum may well have to give precedence to the demands of particular projects and problems. Some potentially evolutionary approaches that appear worth investigating within more traditional methods of teaching include peer group work, mentoring, metacognition, reflective diaries, concept maps, experiential learning, use of information sources including newspapers and the use of ICT. Even a techno-sceptic can surely accept that computers should have a key role to play in promoting independent learning. However care will be needed if we are not merely to convert learners from being teacher-dependent to becoming software-dependent.

3. Objectives and good practice

The group discussed how we should approach the task of developing independent learners. Four aspects all of which depend on each other were considered. Group members also exchanged relevant good practice from their own universities.

I. Education process

1. Does the education process need to undergo fundamental change in order to develop independent learners in Chemistry?
2. Which actors are involved in developing independent learners?
3. At what stage of a programme of study should the development process begin?

II. Didactics

1. Which teaching methods best support an independent learning process?
2. How can practical courses be used to help the development of independent learners?
3. Which skills need attention?

III. Assessment and diagnostics

1. How should assessment be adapted to promote the development of independent learners?
2. How can the problem of heterogeneous pre-knowledge of students be accommodated?

IV. Computers and ICT

1. What roles do computers and ICT have to play in the development of independent learners in Chemistry?
2. Which learning activities can take place in cyber space?

I. Education process

The Bologna Process and the development of the “Eurobachelor” label[1] provide a formal mechanism to enable students to move flexibly from one European university to another in order to advance their studies or simply to undertake a small part of their programme of education elsewhere before returning to their original university. To achieve this, the ECTS system was introduced and the core areas of chemistry and list of core concepts were determined.[2] European students who graduate with chemistry degrees at a university with a “Eurobachelor” label will:

- have the ability to gather and interpret relevant scientific data and make judgements that include reflection on relevant scientific and ethical issues;
- have the ability to communicate information, ideas, problems and solutions to informed audiences;
- have competences which fit them for entry-level graduate employment in the general workplace, including the chemical industry;
- have developed those learning skills that are necessary for them to undertake further study with a sufficient degree of autonomy.

Members of the "Developing Independent Learners in Chemistry" working group agreed that the current, widespread teacher-centred educational process typically consisting of separate lectures given by a teacher, guided tutorials and labs where prescribed experiments are performed, can not fully support this development. This mode of instruction is usually accompanied at the end by a traditional summative unseen examination. To become an independent life long learner, students must take an active role in a flexible educational process. This means that students must start to take responsibility for learning into their own hands and reflect regularly on their progress. Metacognition, which can be defined as "higher order thinking that involves active control over the cognitive processes engaged in learning",[3] also becomes an important attribute. The classical setting of one teacher per course needs to be replaced by a more open approach where other experts and peers also become actively involved in the students' learning process. The role of the teacher now becomes that of a coach; the "guide on the side" replaces the "sage on the stage". Within a course, students should have access to a range of different learning resources, e.g. interaction with guest experts from within the university and from further afield, web-based tutorials and on-line self assessments to check progress, searchable electronic databases, journals and newspapers. Last but not least, the exchange of knowledge with peers becomes an important aspect of the learning process (e.g. peer review, collaborative learning, (electronic) group discussions).

To change the education process from teacher-centred to student-centred, three actors: the student, the teacher and the university, must all be involved. If students are to take responsibility for their own development it is essential that teachers employ teaching methods that stimulate independent learning and provide appropriate support to enable them to become independent. The university must also facilitate this educational change by providing suitable training for teachers and teaching assistants to enable them to fulfil their role. The introduction of innovative teaching approaches should become an integral part of curriculum development in support of the Bologna process. It has to be realized that such activities will require both the expertise and precious time of the university teacher who is also a researcher. Extra funding will be needed to enable university teachers and educational experts to work together on innovative educational development projects. Universities should encourage the publication and dissemination of any good practices developed and provide opportunities and support for teachers to share and discuss their experiences with peers. Careful consideration will also need to be given to the staff student ratios and resource implications associated with the implementation of appropriate good practice.

Many students currently arrive at university unable to take responsibility for their own learning. We recommend that the development of independent learners should start at the very beginning of their programme of study. Therefore, the first year is particularly important for the process. Inquiry-based labs can help students to develop their scientific method and creativity.[4] (See also below under Didactics). In addition, inquiry-based learning can awaken interest in science thus increasing students' motivation for learning.

- ***Good practice:* "Scaffolding", Dublin Institute of Technology, Ireland**

At Dublin Institute of Technology (DIT), changes have been made to the teaching and learning activities and strategies being used in order to support learning and improve retention for non-traditional first year students studying Chemistry. 'Non-traditional students' in this case are understood to be students who, in the past, wouldn't have gained a place in third level education due to their performance at second level. This project has been underway since September 2001 and is particularly targeted at providing support for those who have not studied Chemistry at second level. The objective is to apply the scaffolding approach to support learning and to allow students to develop effective study skills so that, by the end of their first year, they are equipped to become independent learners.[5]

II. Didactics

Problem oriented learning and interactive teaching approaches will promote active behaviour in learners. These teaching methods support not only the development of knowledge but also of skills and attitudes. A student's willingness to take responsibility for his or her own learning will be stimulated by competence oriented and self directing education processes.

Among process-based and learner-oriented teaching models, the most learner-focused method is instructor scaffolding of learner self-assessment and reflection.[6] The scaffolding of instruction facilitates a student's ability to build on prior knowledge and internalize new information and so to reach his or her full potential.[7] A scaffolding teaching strategy is therefore recommended particularly during the first year of study. Teaching methods that support these strategies are integrated and often involve collaboration between students in groups working on open-ended problems or projects. Collaboration between peers and peer assessment therefore become important components of the learning process. In lectures, gapped handouts can be used to ensure that students are more active. In addition, students can be directed to textbooks and given questions to answer from their reading.[8]

Practical courses are crucial for the training of any chemist. Inquiry-based lab projects can take place within the actual research groups at a university even in the early stages of a programme of study. At the end of every laboratory session, students should be encouraged to discuss the experiments and their outcomes in a group. This reflection stimulates better learning and better understanding of the chemical concepts involved for the particular experimental project.

Study skills[9] including time management skills, thinking skills, working with others, and reflection need to be highlighted during subject-specific courses from the first year of study. The generic competences, subject-specific skills and cognitive abilities which have to be developed during the "Eurobachelor" are listed in the report of the Tuning Educational Structures in Europe project.[10] The ECTN working group on Core Practical Skills defined the practical skills required of all graduate chemists in 1999. Attention was given to transferable skills such as working to deadlines, report writing, safety awareness and team work.[11]

To support skills development, feedback from the teachers and facilitators/coaches is crucial. A digital portfolio can be used as a tool to support students in performing self assessment and reflection. For example, a check list and a skills record[12] can be used to support the reflection and future planning of the students as they identify the skills that they possess and those that they still need to develop.

Members of the "Developing Independent Learners in Chemistry" working group also identified motivation to study Chemistry and engagement of students as an important enabler. An emphasis on the impact of Chemistry on peoples' everyday lives and contextualisation of topics being dealt with (e.g. pharmaceuticals, cosmetics, food, sustainable energy) can help a great deal in this regard. Recognition of the experiential learning that students have already gained in everyday life can also be incorporated in this way.

- ***Good practice:*** **"Problem Solving", Department of Material and Earth Science, Polytechnic University of the Marche, Italy**

Cooperative learning is a method of active learning where students are interactively involved in the learning process. Students tackle problems in groups and are assigned certain roles (Problem solver, Sceptic, Checker and Recorder) and follow a structured procedure under conditions that meet the following five criteria of cooperative learning:

1. Positive interdependence. Team members must rely on one another to accomplish goals.
2. Individual accountability. Members are held accountable for (a) doing their share of the work and (b) mastering all of the material.
3. Face-to-face interaction. Some or all work is done by members working together.
4. Appropriate use of interpersonal skills. Team members practice and receive instruction in leadership, decision-making, communication and conflict management.
5. Self-assessment of group functioning. Teams periodically reflect on what they are doing well as a team, what they could improve and what they will do differently in the future.

According to this method, the Problem solver has to think aloud and the Sceptic has to understand the solution, asking for explanations when necessary. By working in a group, students activate critical thinking processes. So the role of the Sceptic is very important, especially if he/she helps the Problem solver to think beyond the usual assumptions. Because the roles rotate for every new problem, each student has the opportunity to improve her/his capacity in the analysis, synthesis and verification of the process. Thinking aloud has the additional benefit of slowing down the thinking process so that reasoning can in general be more effective. Constructing the solution in the group, negotiating the meaning, explaining inferences, teaching one another and making sense of relationships facilitates a deeper understanding of the solution. Helping groups to work together fruitfully requires competence in applying the cooperative learning method and considerable effort from the teacher/facilitator is therefore likely to be needed.

Students studying on the Chemistry course in the Department of Material and Earth Science spend less class time on lectures and about half the time or more on solving problems. The students work in randomly formed groups of three students. In an introductory session lasting about 20 minutes, students receive instructions on concept maps and are shown examples of concept maps made by the teacher and by previous students. The teacher also explains how they are expected to act while working in groups according to their different roles and the particular tasks involved in each role.

The teacher gives feedback on *every* problem solved. Occasionally, one of the students will be asked to come to the blackboard to answer some questions about the material reported on a map. This encourages students to study the underlying theory even in cases where this has not already been covered by the teacher.

The academic performances of over 3,500 students have been analysed and show a strong correlation between marks obtained on the Chemistry module and overall degree results. Students seem quite happy to work in this way and to adhere to the rules: in the 50 hours of the course more than 1,900 problem solutions were collected and corrected. All the students derive some benefit from this didactic approach. Although a large majority of students arrive at the university with little interest in Chemistry, they become more interested in the subject once they start to accept more responsibility for their own learning. A post-course survey showed strong support for this style of teaching.

- ***Good practice:*** **"Learning Groups",[13] University of Ulster, Northern Ireland**

Although peer group work offers significant pedagogical advantages to learners, there are also a number of potentially serious disadvantages. A particularly difficult problem that we have encountered arises from the conflict between Learning and Team Work. It is important to recognise that the optimum arrangements for promoting group learning will not correspond to those best suited to tackling a real life project. A real project tends to focus on achieving the best results while group learning needs to focus on achieving the best learning outcomes. Thus, if a group is given a task, there is a tendency to try and have each part of the task carried out by the individual who is already best at this task: titrations by the most competent practical worker, calculations by the most numerate and oral presentations by the most confident. While this may well evidence good team work and indeed produce the best overall result, it certainly isn't likely to promote the most effective learning, which is surely our aim.
However, when learners work in groups they can have the opportunity to take on different roles. It is important that students be encouraged to work on aspects where they may be lacking confidence. Students can be encouraged to think about their learning priorities by asking them to fill out pre-activity questionnaires in which they indicate what they consider to be their strengths and weaknesses with respect to the tasks that will be required. Students can then be encouraged to take on tasks for which they have identified a particular weakness while group members identifying this as an area of strength can be encouraged to support and help if needed. This approach, while pedagogically sound, will be undermined by a conventional approach to assessment. Success will therefore depend on the use of appropriate assessment strategies that are aligned with the desired learning outcomes.

- ***Good practice:*** **"Studio Course", University of Amsterdam, The Netherlands**

The integration of traditional forms of education (lectures, tutorials and practicals) in a student-oriented, interactive manner with intensive use of ICT was the subject of the educational development project "Interactive Learning Environment for Science Subjects", a joint project between Utrecht University and the University of Amsterdam.[14] Use was made of a specially designed, multifunctional space: the Studio Classroom.[15] The so called "studio approach", led to very good results in a number of science courses.[16] The motivation of the students was high and they achieved good results in courses where students traditionally experience difficulty, e.g. Introductory Physics, Structure of Matter and Mathematical courses, such as Modelling and Programming. In a studio course setting, any misconceptions that exist can be identified by the teacher at a relatively early stage. Another important aspect of the project was the provision of tailor-made support and guidance to teachers involved in its implementation.

- ***Good practice:*** **"Academic Competences and Portfolio", University of Amsterdam, The Netherlands**

The development of academic competences in the Bachelor of Chemistry at the University of Amsterdam, the Netherlands is integrated into subject specific courses. The integration of research and communication skills has proved particularly successful in the case of second year projects where students, working in pairs, carry out scientific research and present their findings to colleagues. Each pair joins one of the research groups in the Department of Chemistry for four weeks to work on a small research project and to produce a report and have it assessed. At the end of the four weeks, all research projects are presented at a conference with students acting as chairmen for all of the sessions. A panel of teachers assesses each presentation and gives the students feedback on the work presented.

Every bachelor student has to present evidence of his of her academic competence level in order to graduate. Students can use a digital portfolio to support the development of academic competences, to reflect on their development and to get feedback on progress. This programme which was introduced as a pilot in 2003 provided students with a self assessment check list of skills. Students who take part in the programme get 3 EC (European Credit) points towards their bachelor degree. About half of the students systematically used the digital portfolio during their bachelor studies.

- ***Good practice:*** **"Learning Logs", University of Ulster, Northern Ireland**

In an attempt to encourage students to identify and confront learning difficulties, they have recently been required to keep a diary reflecting on their Chemistry learning. Each week, the students record what has been covered, how comfortable they are with the new material and the steps they intend to take to deal with any problems that they have identified. To encourage participation, the "logs" make a small contribution, typically about 10%, to the students' coursework mark. Early results have been somewhat mixed as to date many students have merely identified the topics being covered in lectures without reflecting on their own learning. However it is hoped that students will begin to engage more fully as they become accustomed to this approach.

- ***Good practice:*** **"Active Learning", Dublin Institute of Technology, Ireland**

The project at DIT to support learning among non-traditional Chemistry students already mentioned involved several changes to teaching and learning strategies;[5] the tutorial system was improved to promote active learning and peer learning (renamed 'problem-solving workshops'), a virtual learning environment using Web-CT software (including development of self-study quizzes with feedback) was introduced, a multirepresentational approach to cater for different learning styles was developed (molecular models, computer animations and simulations, visual images), study skills were integrated into the subject material, the material taught was contextualised and relevant visual images used, lab experiments were made more relevant and engaging, a team-teaching approach was used and learning outcomes were expanded to include transferable skills (teamwork, peer teaching, communication skills).

Since 2005, project-based learning lab projects have been introduced for Chemistry students in the second year of their programme of study. The students work in groups and are assigned a research question to examine (e.g. To examine the chemicals in cosmetics, To determine how effective sunscreens are). They must research their topic, prepare their project plan and risk assessment, document their work in a research log and present their results to their peers and tutors. This approach has proven to be very effective in promoting an independent approach to learning among the students involved.

- ***Good practice:*** **"Problem-based laboratories", Dublin City University, Ireland**

In first year at Dublin City University (DCU), the approach adopted in the Chemistry laboratory has been one of encouraging the students to engage fully in the laboratory exercises. Rather than carrying out pre-designed prescriptive laboratory tasks, the students are given a problem for which they must find a solution experimentally. This involves students working in small groups of 2-3 deciding on an experimental design and then, after appropriate safety checks have been carried out, performing the experiment. Students are given a pre-lab exercise along with the problem and this is submitted and discussed at the start of the laboratory session. Several different reporting procedures are used for the submission of work, ranging from standard written laboratory reports, to debates and poster and oral presentations. This has proved very effective in promoting student engagement with the tasks and understanding of the concepts involved. Students also more readily see the relevance of laboratory work and find the activities more enjoyable.[17]

- ***Good practice:*** **"Laboratory courses", School of Life Sciences, The Robert Gordon University, Aberdeen, Scotland**

Laboratory skills[18,19,20]

On the Applied Chemistry degree course at The Robert Gordon University, the traditional practice of tying laboratory work to lecture courses was abandoned in favour of a more integrated approach to learning. So considerable care was taken to devise a laboratory programme, which not only crossed the traditional subject boundaries of chemistry, biology etc. but also followed a progression of assessment and learning strategies. In stage 1, the work involves mainly prescriptive exercises, which fall into the category described by Meester and Maskill[21] as "controlled" experiments *i.e.* those in which the answer is known in advance, however at the end of the year students are given a problem-solving exercise to analyse common household products (see more detail below). In stage 2 and 3, the work progresses from these types of experiments to open-ended experiments and group exercises. The culmination of the laboratory programme in stage 4 involves a substantial individual assignment (the Honours Project). In this double module, students demonstrate their initiative and problem-solving abilities.

This programme has sought to improve the laboratory programme by

- facilitating the learning of basic skills and techniques necessary for all professional scientists;
- integrating and applying specialist knowledge and skills;
- introducing higher level tasks sequentially;

- developing transferable skills (e.g. communication, ICT, group work, project management) by assessment;
- maximising the opportunities for student-centred learning.

First year extended experiments'

In order to introduce students to some of the skills involved in carrying out an analytical investigation, the final exercise given to students in the first year was an analysis of some common household products such as vinegar, baking powder, fruit juices and squashes. The exercise involved planning, identifying and carrying out procedures and interpreting the results. Whilst the procedures tended to be simple titrimetric ones, the application was non-trivial for these students. Feedback from the students showed that they found it challenging but also satisfying as they were responsible for their own work. Our experience with this approach has highlighted to us some of the limitations of the "recipe" laboratory exercises and it is regarded by both students and demonstrators as an effective learning experience.

III. Assessment and diagnostics

Assessment drives learning and Ramsden[22] has asserted that "the assessment IS the curriculum as far as the students are concerned." Therefore, the assessment strategies employed will need to be changed to reflect any recommended changes in teaching methods. It has often been the case that reliability rather than validity was the driving force for assessment. Norm-referenced assessment has traditionally been employed but criterion-referencing is now the recommended approach.

New additional objectives become important in courses where students work on projects and open-ended assignments because different generic and subject–specific skills are also being developed. Thus, assessment needs to change and become more competence based, with students preparing project reports and giving presentations about the outcomes. Understanding of basic concepts can be tested in assignments where concept maps are developed. Lab skills including accuracy, record keeping and safe practice can be assessed in "open book" practical tests.

In the key document of the Tuning project; Learning, Teaching and Assessment,[23] the types of assessment suitable for different teaching methods are discussed. According to this document, generic skills do not need to be taught separately from the subject-specific competences. In fact, it is strongly recommended that the teaching of transferable skills should be integrated into subject teaching instead of being "bolted on", so that their relevance and significance will be made apparent to students.[9] Peer assessment can also be used as a method to stimulate independent learners although adequate training in peer assessment strategies is necessary to eliminate rating errors.[24]

In addition, demystification of the marking process is important, particularly for first year students. A method often employed to help learners to understand what is required in order to perform well against the assessment criteria is to show them anonymous pieces of work from the previous year, ask them to decide on a mark and then discuss with them the mark that was actually awarded.[9] Some early assessment to provide timely feedback in first year is also recommended.

The main objective of the Tuning project was to contribute to the elaboration of a framework of comparable and compatible qualifications.[10] This will make it possible for students to move flexibly from one university to another and follow their own individual learning paths. Due to this increased mobility and flexibility, it is to be expected that the pre-knowledge students have will become more heterogeneous. In such a situation, every student will need to take responsibility to brush up on any gaps within his or her own pre-knowledge. Universities need to make available opportunities for students to do this in a flexible way and at different stages in the curriculum. Lack of pre-knowledge in Mathematics, for example, is a particular problem because the understanding of many Chemistry concepts often depends on appropriate pre-knowledge in Mathematics. Measures to build up students' pre-knowledge that are flexible and that can be modified to suit the situation are helpful at all stages of a course. Regular electronic diagnostic tests can be used to determine gaps in the knowledge of a particular student and give an instant feedback. Where necessary, extra help can then be provided by teachers or peers. This can be organised in special flexible brushing up sessions or blended learning courses. (Blended learning is a model that uses a mixture of both face-to-face sessions and e-learning.)[25]

▪ *Good practice:* "Assessment of Practical Work", School of Life Sciences, The Robert Gordon University, Aberdeen, Scotland

The method most usually used to assess laboratory programmes is to give a mark based on the laboratory report for each experiment. However writing such reports is a task that students find tedious and whilst the production of a good report is a skill that must be acquired it is by no means the only way that laboratory experiments can be assessed. Instead of writing up a formal report for each experiment, students are now required to keep a laboratory diary throughout the whole of the laboratory programme. This provides a record of all work carried out in the laboratory and must include the date, the title, aims, results, calculations if appropriate, discussion of results and conclusions. It is however written up as much as possible during the laboratory session. In stage 1, this record is marked regularly but only one experiment, the extended exercise on household substances, is required to be written up as a formal report.

From these early assessment procedures a range of other assessment strategies is gradually developed throughout the rest of the laboratory programme. These include:

- Inspection and marking of laboratory diaries from time to time, but students are now interviewed and must be prepared to discuss and defend their record.
- Laboratory conduct mark.
- The production of fully written laboratory reports for randomly selected experiments.
- Group exercises that are assessed by oral presentations and also include an element of peer assessment.
- Poster presentations and interviews as well as a formal report are required for the Honours Project.

This good practice has shown that the progression from simple investigative procedures to the lengthy and more detailed Honours Project using a variety of assessment strategies can be a rewarding, enjoyable and worthwhile experience for our students.

▪ *Good practice:* "Support Clinics", Dublin City University, Ireland

At Dublin City University, students can visit the "Maths Learning Centre" which is a drop-in centre for all students. The Centre encourages students to attend from the

beginning of their studies and helps them to identify any particular gaps in their prior knowledge. Diagnostic tests at the beginning of the year identify the ‘at-risk’ students and these are particularly encouraged to attend the clinics.[26]
A “Science Drop in Centre”, which is staffed by post-graduate students has now also been opened. This operates on the same basis as the Maths Learning Centre but is more restricted in its opening hours. It encourages students to be more aware of gaps in their prior knowledge and offers a supportive environment for students to obtain help for basic understanding. Both centres are particularly well used during examination revision times.

- ***Good practice:*** **“Students’ Maths Learning Centre”, Dublin Institute of Technology, Ireland**

Dublin Institute of Technology provide a Students’ Maths Learning Centre (SMLC), a drop-in centre that offers assistance with Maths for all students in all faculties. This is supplemented by an online support system. The mission statement of the SMLC is that it encourages students to become independent autonomous learners with greater confidence in their mathematical abilities and a better overall understanding of maths.[27]

- ***Good practice:*** **“Brushing Up With the Web”, University of Amsterdam, The Netherlands**

Many students face problems when they need to apply their pre-knowledge in Mathematics. This is not only in pure Mathematics courses but also in Chemistry courses that require Mathematical pre-knowledge (e.g. Quantum Chemistry). In the Netherlands, several innovative educational projects are going on at the moment where different universities are working together on this problem. The Brushing Up With the Web project (Web-spijkeren, University of Amsterdam, Erasmus University Rotterdam, Maastricht University) (2004-2006)[28] develops innovative teaching approaches comprising various ICT tools. The first step is frequently an individual online diagnostic test. This is followed by independent and/or shared knowledge acquisition under the guidance of a teacher (with modules in the electronic learning environment). Finally, an online test assesses whether the required level has been reached. During the course in Quantum Chemistry, the students regularly assess their pre-knowledge as this is necessary to understand the Quantum Chemistry concepts. They complete online diagnostic tests based on Computer Algebra (Maple TA). Thus, they brush up on their pre-knowledge in Mathematics just in time to be able to follow the next lecture in Quantum Chemistry.
A Special Interest Group on pre-knowledge in Mathematics has been formed in the Netherlands to coordinate the efforts of all the parties involved nationally with this problem and to exchange experience and best practice with interested groups from other European countries.

- ***Good practice:*** **“Support for Learners”, School of Life Sciences, The Robert Gordon University, Aberdeen, Scotland**

At The Robert Gordon University, students can use a Study Support Centre. This facility aims to provide students in their early years at university with support and tutoring to help enhance their academic abilities and overcome study related difficulties. The support provided encourages the improvement of skills, increasingly building up confidence with one-to-one study and tuition groups. The centre helps with maths, writing skills, study skills, statistics and ICT skills.[29]

(i) The Maths Centre offers to students diagnostic tests, quick reference guides, practice and revision materials, video tutorials, workbooks and online practice exercises on many branches of Mathematics.

(ii) The Writing and Study Skills Support covers essay structuring and planning, report writing, referencing and presentation skills. Students can also get limited help with basic spelling, grammar and punctuation problems along with advice on formal academic writing styles and conventions and study skills.

(iii) Statistics Resources helps students to improve their analysis of collected data, using statistics packages such as Excel, MINITAB, SPSS and STARS - Creation of Statistical Resources from Real Datasets

(iv) ICT Skills Resources offers help in the basic use of ICT, e.g. Microsoft Word, PowerPoint, Excel, Project and Access.

IV. Computers and ICT

Students use communication technology today very readily. Children chat online daily with their friends, they use e-mail and most children already have a mobile phone by the age of 10. This makes it easy and also natural for them to use this technology in education. Students can readily collaborate online as they work together in groups sharing online space and discussion boards. Online communication is possible in synchronous or asynchronous settings and this can accommodate situations where the students and the teachers are not in the same place and where they may or may not be online at the same time.

Electronic learning platforms can be used to support flexible learning. Students can access teaching materials and resources at any time, use different communication tools and find digital tests from any online computer. Students can visit the virtual learning space of their university courses literally 24 hours a day and 7 days a week and this has been observed in the yearly research on the behaviour of students using Blackboard electronic learning platforms at the University of Amsterdam, the Netherlands. Similar results have been observed with the use of the WebCT electronic learning platform at Dublin Institute of Technology, Ireland. Blackboard has recently merged with WebCT, the company that provides one of the other major web-based learning platforms available. This should facilitate increased collaboration between universities across Europe.

Development of generic as well as subject-specific competences listed in the Tuning project document[10] can be supported using computers and ICT technology.

Several learning activities can take place in cyber space enabling students to always have ready access to many different resources, including sources of primary literature. This requires them not only to be able to find information but also to evaluate its quality and relevance and to be able to cite and reference sources correctly when reporting. The development of information management and information literacy skills needs attention and this should be included in the teaching activities within courses.

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 solve more complex and realistic problems. Nowadays, research software is very user friendly and can often already be used by students.

As mentioned in the previous section on Assessment, computers can be very useful tools for diagnosing students' pre-knowledge. Adaptive electronic tests can be used. The computer gives feedback to individual students so that they know where there are gaps or problem areas in their present knowledge that they need to brush up on. This approach also helps students to develop the metacognitive skills that are essential for independent learning.

Development of online courses that are activity-based instead of just content-based has become more widespread in the recent past. The additional flexibility afforded by web-based learning as well as its suitability for collaborative group learning through the use of discussion boards and synchronous online communication has provided a new means of developing independent learners. Thus, the internet is no longer used only to provide learner supports and resources but can also be employed as a framework for learner activities, particularly group activities.[30] Academic staff will require training to develop the skills necessary to facilitate online discussions but many universities are now providing this.[31]

▪ *Good practice*: "Self-study quizzes", Dublin Institute of Technology, Ireland

At the Dublin Institute of Technology, first year students use a Web-CT virtual learning environment to access self-study quizzes with instant and detailed feedback to determine how well they understand and can apply material that has been introduced in lectures.[32] In order to encourage use of these resources, an online assessment test that uses a selection of the self-study quiz questions is set towards the end of the academic year. Thus, students who have accessed the quizzes already have an advantage and can get a good mark.

▪ *Good practice*: "European Virtual Seminar", Several European universities

An example where online collaboration between students from different European universities takes place is the European Virtual Seminar (EVS) course.[33] The didactic concept of the EVS is that of virtual collaborative learning, based on ideas of constructive learning theories. To make this idea work, different institutions for higher education participate in the EVS and invest staff time, expertise and resources in the development of this innovative educational project. 16 European universities are involved with this course. The students work together in interdisciplinary groups on case studies about sustainable development in Europe. The students never meet each other face-to-face during the project and communication takes place over the internet. Blackboard, the electronic learning platform which is intensively used by several universities to support independent learning, is used in this course.

The development process of the EVS is co-ordinated by the Open University in the Netherlands. Participating institutions co-operatively develop the didactic concept and web based course materials, and they are collectively responsible for the provision of tuition in terms of input of staff time, expertise and resources.

▪ *Good practice:* "Moodle Support", Dublin City University, Ireland

The use of Moodle, an electronic learning platform, has been encouraged in DCU and is widely used for provision of lecture notes (in full or in part), quizzes, discussion fora, and assignments. There is some evidence that first year students will only interact with quizzes and other support material if these form part of the assessment. Also, if quizzes are considered too difficult, then generally if they are not assessed, they will not even be attempted.[34]

- ***Good practice:*** **"On-line help for on-campus students", School of Life Sciences, The Robert Gordon University, Aberdeen, Scotland**

The Robert Gordon University has developed its own virtual learning environment called the Virtual Campus.[35] It provides a comprehensive infrastructure and facilitates interaction between staff and students supporting course delivery, tutoring, and discussions. For modules given to first year students, not only is the lecture material posted up for downloading but other support materials have also been uploaded to aid those students who need more help or background information on course content. For instance, for the self study access materials in chemistry, useful website addresses, computer quizzes, and sample exam questions are provided. All are aimed at helping the students to take charge of their own learning.

122 first year students were asked to fill in a questionnaire about how they used the support materials on the Virtual Campus. Sixty four replies were received. 100 % of the sixty four downloaded the lecture notes, however when asked 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 response dropped to only 24% when students were asked if they used the recommended text book.

The distance-learning mode of the Diploma in Applied Chemistry is delivered *via* the University's Virtual Campus. The Virtual Campus provides a comprehensive infrastructure for distance learning, providing the flexibility for study in the students' own time. The learning materials are received through the Internet. The Virtual Campus facilitates interaction between staff and students and supports the course delivery by the use of discussion fora, community groups and e-mail. A large part of the learning experience is delivered by tutorials online or by e-mail. As for on-campus students, quizzes, crossword puzzles and other support materials have been devised as well as the main course content. Students are also directed to suitable websites. However face-to-face tutorials can be arranged if required for local students. The practical element of the course is taught by two one-week summer schools.

4. List of recommendations

I. Education process

- The education process should change from teacher-directed to student-directed.
- Three actors are involved in this process: the student, the teacher and the university. Universities should organise regular training for teachers and teaching assistants to help them to fulfil their new roles as facilitator and coach in the education process.
- Development of independent learners should begin in the first year at the start of a programme of study.
- Teachers need more recognition for the work they do on educational development. Extra funding will be necessary to support didactic development projects where teachers and experts can work together.

II. Didactics

- An interactive learning approach employing problem based and inquiry based learning is recommended.
- The student's responsibility for his or her own learning process can be stimulated in a competence oriented and self directing education process.
- Development of the generic and subject-specific skills required should become an integral part of all subject-specific courses.
- Feedback from teachers, coaches and peers on the performance of a learner is very important. Skills records and (digital) portfolios can be used to support feedback activities.
- Inquiry-based lab projects should take place within actual research groups of the university at an early stage of a programme of study wherever possible.
- A scaffolding teaching strategy is recommended. It is particularly important to implement this approach in the first year of study as this is when learning support is most important.
- To develop research skills and stimulate better understanding of chemical concepts, students should discuss experiments and their outcomes in a group at the end of laboratory sessions.
- Attention also needs to be given to developing students' metacognitive processes.

III. Assessment and diagnostics

- Assessment strategies should be realigned in the light of didactic changes and should become more competence based.
- Project reports and presentation and discussion of outcomes should become integral parts of the assessment process.
- Concept mapping can be used to test understanding.
- Assessment needs to take account of the heterogeneous background knowledge of students.
- Special initiatives and projects to allow learners to brush up on gaps in their knowledge should be introduced.

IV. Computers and ICT

- Access to teaching materials and tools needs to be arranged according to the 24/7 principle. Electronic learning platforms can support this type of flexible learning.
- Development of information management and literacy skills must be addressed and these should be included in the teaching activities within all chemistry courses.
- Students need to be able to use different online resources including primary literature sources and to evaluate the quality and the relevance of the information found.
- Within courses, computers should be used as research tools to solve real and more complex open-ended problems.
- Time and place independent communication with peers, teachers and experts should be encouraged.
- Online collaboration of students at different locations and also in interdisciplinary groups is recommended. Thus the responsibility of each student for his/her own development is strengthened.
- Online diagnostic tests to assess pre-knowledge are recommended.

5. Summary

Although it is now widely accepted that if standards are to be maintained in our universities, primary cycle students will need to start to take more responsibility for their own learning, today's undergraduates appear both unwilling and unable to do this. Such students clearly need our help and encouragement. Although a wide range of educational innovations have been introduced into university courses over the past two decades, virtually no attempt has to date been made to evaluate the effect that these have had on helping students to become more independent in their approach to learning. However, it is clear that most pedagogical studies could easily include this dimension. There is much good practice out there; it is not ideas that we are currently lacking but the commitment to evaluate the effectiveness of these ideas.

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