Chemistry LabSkills: Software to Support Laboratory Skills from Schools' Pre-University to University Foundation Courses

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Abstract

The UK's Centre for Excellence in the Teaching and Learning of practical chemistry, Bristol ChemLabS, has completely rethought the way its practical chemistry course is delivered and has created an e-learning resource called the Dynamic Laboratory Manual (DLM) to support this. The emphasis on e-learning allows students to engage with the material as a pre-lab exercise. The concepts from the full undergraduate degree DLM have been adapted for the UK's pre-university courses and for generic foundation chemistry courses at universities worldwide.

Keywords: Bristol ChemLabS, e-learning, pre-lab, LabSkills, practical, supported self-study

Introduction

Chemistry LabSkills is an unusual piece of software for several reasons [1, 2]. First it was produced by a university chemistry department who had developed a novel way of supporting its undergraduate practical skill development course as part of an honours degree program. Second it is software that is designed to aid practical work in chemistry and not to replace it by simulated experiments. Third it was produced in conjunction with an educational software company, Learning Science, whose staff have a strong science background themselves, particularly in Chemistry.

During the period 2005-8 the School of Chemistry at the University of Bristol, the home of Bristol ChemLabS, the UK's Centre for Excellence in the Teaching and Learning of practical chemistry, totally revamped its traditional practical courses. It was replaced with a practical skills course that was divorced from the lecture program and from the false segregation of organic, inorganic and physical chemistry. This course was supported by a major investment in e-learning software (called the Dynamic Laboratory Manual or DLM) that also allowed formative and summative assessment of practical skills. One of the many innovations of the Bristol ChemLabS project was the establishment of the full-time post of School Teacher Fellow [3,4]. The STF is an experienced secondary school science teacher and the benefit in the 'front loading' of practical work to pre-university level chemistry was obvious to someone from that background. With a resident STF in post it was possible to develop a pre-university DLM called Chemistry LabSkills and from this, a university foundation level LabSkills package was also developed.

So what is LabSkills?

LabSkills is innovative software that helps chemistry students develop essential practical skills. It is made up of 50 chemistry modules, each containing a variety of activities for study that are both interactive and engaging. For many elements there are virtual experiments that students can explore, opening taps, adjusting heating and many more, that allow students to understand what is going on and why a practical may or may not work if certain things are done and in a certain sequence. Students learn quickly, gain confidence and perform better in practical work having used a resource whose activities are challenging and fun; being able to rehearse practicals beforehand in a virtual environment has been shown to have a marked impact on cognition [5,6].

The LabSkills resources include common techniques and experiments, best practice, safety, videos, calculations, tests, revision and exam practice questions. Each technique contains interactive simulations which are intuitive and media-rich. These provide multiple opportunities to explore techniques through trial and error, addressing all common student mistakes with questioning, hints and feedback. Setting up equipment correctly, optimising experimental conditions and visualising molecular behaviour during instrumental analysis is also covered and exam-style, multi-step questions are provided with optional interactive hints and feedback throughout.

There are in built elements of skills and competency training where there are questions and worked examples with interactive hints and feedback on topics such as the understanding of basic chemical tests and the appropriate choice of equipment, mathematics within chemistry covering errors, accuracy, precision and significant figures, and in balancing equations and calculating quantities, concentrations, reaction rates and equilibrium constants.

The Lab techniques modules are made up of several elements. There are simulations that allow the student to work out why a piece of apparatus is set up as it should be. These scenarios start from the point of view of the inexperienced student. Once the correct arrangement of the equipment has been mastered there is a video section. Here short sections of video clips show the latest equipment being used and provide a step-by-step breakdown of each technique with brief notes which McKelvy (2000) [7] notes is a very powerful aid to cognition. The notes are the sort of information that a teacher or demonstrator would give to a student if they were alongside them in a practical class; the sort of information that comes from experience and that is not found in a text book. There are a few self-test questions to reinforce and consolidate learning for each technique that may be printed out or uploaded to the VLE if required. This facility is not available on the teacher

memory stick only version (see below). The Safety section has interactive images of apparatus with safety and good laboratory practice emphasised.

The software does have examples of experiments where the various practical techniques may be used with interactive images for each experiment broken down with information on background and context, health and safety, experimental procedure and observation opportunities.

Three versions are available for educators; the first is a version that runs on a virtual learning environment (VLE) and a second that runs on an individual computer for seminar work or individual self-study. A third version, with much less functionality for individual students is also available. Details of all products are available at http://www.labskills.co.uk/. In the VLE form, it can of course be used at the place of learning or at home where students can practice in a safe environment and develop skills by exploring simulations, answering questions and correcting mistakes and misconceptions.

Why is LabSkills effective?

The learning resources in LabSkills require students to actively participate in the learning process and to come into lab classes prepared for the practical to be undertaken. The high level of responsive interaction requires students to continually test their understanding of the science and learn from their successes and mistakes. Instant feedback is provided to formative and summative problems which supports students whatever their level of knowledge and understanding.

Using LabSkills, students can prepare for practical classes by exploring the techniques and experiments that they will then encounter in the laboratory itself. They can practice in a safe environment and receive directed and focused feedback on their performance at whatever pace they are working. Virtual glassware costs nothing to replace! The students then can recognise that laboratory classes are there to develop practical skills and are not simply a recipe following exercise.

Implementing LabSkills

The resource can be used in several ways. Before starting a practical ('pre-lab') students can be directed to work through specific sections in the lead up to practical work. This supported self study may be used as preparative work and will result in more effective use of valuable laboratory time. Students can submit printed test results if necessary. Being fully SCORM compliant LabSkills allows results to be viewed electronically through the institution's learning platform. In seminars and tutorials the whiteboard option allows the screen size to be maximised so that interactive elements can be used for whole class reviews and group discussion. During the practical class the software may be run on PCs and whiteboards in the laboratory as an aide memoire. Where needed LabSkills provides an effective way for students to actively revise practical work away from the laboratory when repeating the experiment is not possible.

LabSkills also has a number of reference resources; the equipment glossary with descriptions of commonly used equipment, reagent glossary with descriptions of reagents commonly used at this level, lab health and safety comments, a scientific calculator and of course a periodic table.

There are fourteen self-contained modules covering the main lab techniques commonly used at this level shown in Table 1. Each module contains a mix of simulations, videos, safety resources and multiple choice tests.

Table 1. Preparation and purification techniques covered.

Filtration	Reflux
Recrystallisation	Distillation
Melting point	Solvent extraction
Thin layer chromatography	Collection of a gas
Colorimetry	Titration
Enthalpy change of combustion	Titration curves
Enthalpy change in solution	Electrochemical cells

Added to this are sixteen additional modules consider core laboratory competencies covering basic skills, lab calculations, and chemical tests shown in Table 2.

Table 2. Chemical tests, basic laboratory skills, chemistry calculations and instrumental techniques.

Tests and Observations	**Basic skills**
Tests for inorganic compounds	Weights and measures
Tests for organic compounds	Preparing solutions
Transition metal compounds	Heating
Lab calculations	**Instrumental techniques**
Stoichiometry and yield	Mass spectrometry
Quantities and concentration	IR spectroscopy
Errors and significant figures	NMR spectroscopy
Reaction rates	GC analysis
Equilibrium constants	HPLC analysis

Twenty widely performed experiments covering preparative, qualitative and quantitative practicals are also included to augment the institutions own practical scripts.

Other Uses and Development of LabSkills

Foundation Chemistry LabSkills is already being used in a number of universities in South Africa and Canada with interest being shown in Australia and the United States. Feedback indicates that a major strength is in the training of the postgraduate demonstrators/teaching assistants so that gaps in their understanding of practical procedure are overcome and a more unified approach to work can be developed. The schools and colleges pre-university version, A-Level LabSkills is already in use

in schools in countries from Mongolia to South Africa as well as widely within the UK.

LabSkills also provides highly effective support for trainee and newly qualified teachers. In partnership with the Royal Society of Chemistry it has been used in over 50 universities in the UK and was available to up skill 1100 postgraduate trainee chemistry teachers through the Discover LabSkills project www.rsc.org/labskills in the last two years. The first year of this programme was evaluated by the National Foundation for Education Research NFER) an external body [9].

Within the School of Chemistry at the University of Bristol the Dynamic Laboratory Manual methodology is already being developed and implemented in two Doctoral Training Centres (DTCs), one in Chemical Synthesis and the other in Functional Nanoscience. DTCs are EPRSC-funded four-year PhD programmes in which the first year focuses on advanced training in research methods.

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