Context and Problem-based Learning

Tina Overton
Physical Sciences Centre
Department of Chemistry
University of Hull
Hull
HU6 7RX

t.l.overton@hull.ac.uk

Abstract
Context based learning is any learning that places content within a meaningful context. CBL has been demonstrated to enthuse and engage learners and is increasingly being used in sciences, especially at pre-University level. Problem-based learning can be viewed as a sub-set of CBL. In PBL, the context is framed as an open ended problem scenario. The problem is encountered before knowledge is in place and acts as the driver for independent learning. PBL has been demonstrated to enhance understanding, increase motivation and develop a range of transferable skills. The use of CBL and PBL in the physical sciences will be reviewed.

Context and problem-based learning are approaches that are becoming increasingly popular in Higher Education. The aim of this article is to introduce the two approaches and provide some exemplars from within the physical sciences.

What is context-based learning?
Context-based learning (CBL) in its broadest sense describes the cultural and social environment within which students, tutors and institutions operate. This context is influenced by communications media to provide the academic community with a common culture. Hansman[1] states that adult learning only takes place when this context and learning tools or methodologies come together to promote interaction between learners.

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Another aspect of context-based learning is the use of applications to illustrate and illuminate the curriculum. For science students this usually means providing them with opportunities to test theories with real world examples. The use of a meaningful and appropriate context has been shown to motivate and enthuse learners[2,3]. However, introducing these real examples after all the theory has been covered may not be the best approach.

It has been suggested[4] that science concepts exist in three forms which can be thought of as corners of a triangle (Fig 1) and that each form complements the other. These forms are

- the *macro*: what can be seen, touched and smelt;
- the *submacro*: atoms, molecules, structures, forces, etc
- the *representational*: symbols, formulas, equations, etc

Johnstone argues that we encounter life on the macro level. On the macro level science is what students do in the laboratory or experience in real life. However, science, to be more fully understood, has to move to the submicro situation where the behaviour of substances and physical phenomena are interpreted in terms of the unseen and recorded in some representational notation and models. Science is traditionally taught almost entirely from the submicro and representational forms with the macro, or real life, aspects often being divorced from the rest of the subject or added as an afterthought. Where this approach has been reversed to use a real life context to drive the learning evidence has demonstrated that students engage much more enthusiastically with their learning[5-7]. It is this definition of context-based learning that is used in this paper.

Why use context?
An extensive review of 66 studies on interventions with 11-16 year old pupils found that the use of context motivates and fosters positive attitudes to science without compromising learners understanding of scientific ideas[8]. The use of context based learning is increasing in pre-19 education. The Salters A-Level course (*Salters Advanced Chemistry* from http://www.york.ac.uk/org/seg/salters/chemistry/index.html) aims to "emphasise the ways chemistry is applied and the work that chemists do" and includes modules on topics such as 'The Oceans' to teach enthalpy, entropy and solubility and a

module called ‘The Steel Story’ to teach redox, electrochemistry and *d*-block chemistry. The Salters Horners A-Level physics course (*Salters Horners Advanced Physics* from http://www.york.ac.uk/org/seg/salters/physics/index.html) uses modules such as ‘Transport on Track’ to teach force, momentum, electromagnetic forces and ‘Build or Bust’ to teach simple harmonic motion, forces vibrations, resonance and damping. The Higher Education sector has also seen a growth in provision that presents science in real-world contexts, such as forensic science, sports science and astronomy.

have used Barrow’s model to demonstrate that PBL fits easily within the framework for effective learning described by the constructivist learning theory. Constructivism is a philosophy of learning founded on the premise that, by reflecting on our experiences, we construct our own understanding of the world we live in. PBL learning is a process of building on prior knowledge, problem solving, using critical thinking approaches and reflecting[12].

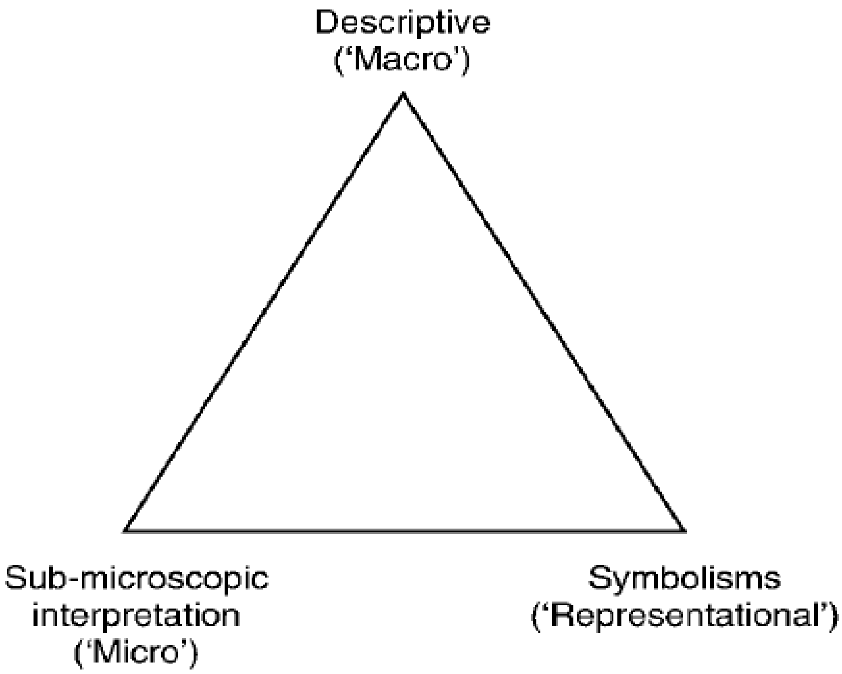

Figure 1: Three levels of science concept representation

What is problem-based learning?
Problem-based learning (PBL) can be considered to be a sub-category of context-based learning. In PBL, as in CBL, the curriculum is organised and driven by real life contexts. In PBL these contexts are presented in the form of problem scenarios. An important feature of PBL is that the problems or scenarios are encountered before all the relevant learning has taken place and act as the driver for new learning. Thus PBL is distinct from problem solving where problems are generally encountered after learning had taken place. A course that is delivered entirely by PBL would have no lectures and students would work in groups throughout the process, with tutors acting as facilitators. A good introduction to PBL has been published by Boud and Feletti[9] which contains short chapters grouped into themes, including getting started, design and implementation, and assessment and evaluation.

Problem-based learning first appeared 1969 as a new approach to medical education at McMaster University in Canada. It was developed as an educational approach drawing on philosophy, psychology, and educational research. According to Barrows[10], PBL can be explained as “the learning that results from the process of working toward the understanding or resolution of a problem”. Savery and Duffy[11]

There has been considerable research carried out that compares PBL medical students with traditional medical students. Many of these findings may be generalisable to the application of PBL in other disciplines. For example, research into reasoning skills found that PBL students tended to reason backwards from clinical information to theory whereas traditional students tended to reason forward from theory and stayed closer to clinical facts[13]. There is evidence that PBL students perform less well on written examinations of knowledge[14] but perform better on skills based assessments[15]. Some studies have shown that PBL students show different study skills to conventional students. PBL students have been found to use a wider range of information sources and feel more confident in using information[16]. PBL students have been found to be more likely to study for meaning than conventional students[17].

How does PBL work?
PBL is different from other forms of learning in that the students work in teams throughout and move towards a solution to the problem together by gathering and sharing information and ideas. There are several formal models of PBL and these are strictly adhered to in some disciplines, particularly medicine and associated professional disciplines,

such as nursing. As PBL is relatively new in the sciences, practitioners are developing flexible models of PBL and implementing them in ways that suit their own particular context. Some examples are discussed later. However, the main features of PBL are real world context, group work, problem solving, acquisition of new knowledge and presentation of outcomes or product.

Generally, during the first classroom session the students are divided into groups and presented with the problem. They may brainstorm in order to clarify the nature of the problem and identify their learning needs. They may delegate roles within the groups and share existing knowledge. The tutor's role is one of observation, guidance and support. Outside the classroom session, the students engage in independent study in order to fill any gaps in subject knowledge. They come together again in a group or classroom session to share and critically evaluate resources and information gathered. Using the newly acquired information they work towards a solution to the problem. Again, the tutor's role is one of guidance and support. This cycle of independent study, group interaction and critical analysis may be repeated as many times as dictated by the problem. Eventually the students present their solution and reflect on the process and solution.

A search under 'problem-based learning' using the Google search engine finds eight million hits with no trouble at all.

What about assessment?
As this is a very different type of learning activity it may not be appropriate to assess students in a traditional way. The assessment should be matched to the desired learning outcomes. Assessment may focus on the solution to the problem, or the problem solving process or the skills development aspect. Tutors must decide whether they wish to give each member of a group the same mark or whether they wish to build in an individual element. Students may be involved in assessing each other's contribution to the activity or may be involved in self-assessment and reflection. Useful assessment tools include; reflective logs and diaries, written reports, oral presentations, posters or the product from practical activity.

Examples from chemistry
Context and problem-based learning in chemistry has grown in popularity over the past 5 years and new and innovative examples are continuing to appear. Belt et al have produced a suite of C/PBL resources for analytical chemistry drawing on contexts in industrial, pharmaceutical, environmental and forensic chemistry[6,18]. These resources deliver learning outcomes in analytical chemistry as well as a range of transferable skills. Green chemistry has also been used as a context for chemistry[19,20] where the aim has been to raise the issue of green chemistry as it relates to the chemical industry. In another example, sport was used as the context to meet learning outcomes in biochemistry, simple thermodynamics and materials chemistry[21]. Environmental chemistry is another context that lends itself to delivery of the chemistry curriculum[22]. It might be expected that the traditional branches of chemistry; inorganic, organic and physical, would be more difficult to deliver via context or problem-based learning as the applications and real life contexts are less obvious. Some success has been achieved however and a collection of resources in these braches has been published by the Royal Society of Chemistry[23]. The PBL approach has also be applied successfully to the undergraduate chemistry laboratory. McGarvey has collaborated with industry to produce a suite of physical chemistry experiments[24] and McConnell et al have produced PBL mini-projects which utilise contexts such as cosmetics, food and forensic science[25].

Examples from physics
Problem-based learning in physics has emerged in the UK and Ireland over the last 5 years, largely stimulated by the efforts of groups at Leicester University and Dublin Institute of Technology. A comprehensive guide to PBL in physics which contains a large number of examples, including the work of these two groups, has been published by the Physical Sciences Centre[26].

PBL has been used in the undergraduate physics laboratory[27] and in small group projects[28]. One interesting application of PBL has involved the use of images, rather than the usual textual questions, equations and formulas[29]. An extensive post-16 curriculum uses contexts in sport, food, and the environment to teach basic physics[30]. The authors of this curriculum warn against using contexts which potentially alienate sections of the student population and to take care to consider gender and cultural issues

PBL resources on the web
A search under 'problem-based learning' using the Google search engine finds eight million hits with no trouble at all. Most PBL websites give a definition of the key characteristics of problem-based learning and extol the virtues of the approach. Most give extensive lists of links to other sites and, consequently, almost any PBL website is a reasonable starting point. Few attempt to give any sort of realistic advice on implementation, overcoming difficulties, preparing staff and students or writing problems. Even fewer sites give examples of problems and many that do give materials which are, to say the least, disappointing. Much of what is presented as PBL is really no more than reasonably creative problem solving.

Most quality PBL sites originate in the USA, Canada and Australia. Much of what is available is in Medical education but is often still applicable to other disciplines. Many of the sites are interdisciplinary and provide resources and ideas which many practitioners may find useful. What follows here are brief summaries of the some of the more interesting and useful aspects of several sites on PBL.

Project LeAP (Problem-based LEarning in Astronomy and Physics) was a three-year FDTL project. The project aimed to increase the profile of problem-based learning in university Physics and Astronomy courses. The University of Leicester lead the project consortium, with the Universities of Hertfordshire, Reading, and Sheffield as partners. The project website includes a comparative analysis of PBL within physics, case studies, exemplar support materials for students and tutors, and original PBL problems. Although the project is now completed the webpage remains updated and the PBL work is now sustained under the activities of the π-CETL, Centre for Excellence in Teaching and Learning. An annual PBL summer school is organised each July.
(http://www.le.ac.uk/leap)
(http://www.open.ac.uk/picetl/)

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The University of Adelaide's Advisory Centre for University Education is home to 'Leap into PBL'. This site is aimed primarily at the university teacher who wishes to explore this approach for the first time, but may also be useful to the teacher who has 'dabbled' with PBL. The site aims to provide a structure around which practitioners can build their own course. It includes a step-by-step induction to PBL and covers a wide range of issues such as training staff, preparing students, assessment, evaluation, dealing with non-participation, keeping the groups going, timetabling sessions, etc. It also provides guidance on writing problems that do not gloss over the effort and time involved. This s a very useful and practical site and is a good staring point, especially for the lecturer new to PBL.
(http://www.adelaide.edu.au/clpd/materia/leap/leapinto/ProblemBasedLearning.pdf)

The National Center for Case Study Teaching in Science is a real treasure trove of context-based case studies. There are many examples of cases covering many areas of science and links to a large number of sites which could provide ideas for new cases. This is an excellent place to start if you are thinking of writing your own problems.
(http://ublib.buffalo.edu/libraries/projects/cases/ubcase.htm)

The Problem-based Learning Initiative at Southern Illinois University concentrates mainly on medical education but is very useful for the basics such as the essential requirements for PBL. If you are interested in medical education then they have a range of books, videos, PBL modules and patient simulations to buy. The bibliography is very comprehensive.
(http://www.pbli.org/core.htm)

The San Diego State University Distributed Course Delivery for PBL site provides an on-line workshop in PBL which could form the basis of do-it-yourself staff development. This could be another good starting point for academics new to PBL. The 'Learning Tree' section provides comprehensive coverage of the subject and is particularly strong on assessment, implementation and overcoming barriers and obstacles. The site also includes an extensive bibliography.
(http://edweb.sdsu.edu/clrit/home.html)

The University of Delaware site hosts a number of sample problems taken mainly from the sciences. By far the most useful feature of this site is the PBL Clearinghouse which is a searchable collection of many peer reviewed problems. The Clearinghouse is accessed via an email user name and password but these are available easily and you can be signed up within minutes. Once into the Clearinghouse, users can search by keyword, author or discipline. There is also an invitation to become an author or reviewer. This is a really excellent resource.
(http://www.udel.edu/pbl/courses.html)

Of course McMaster University in Canada has a long tradition in PBL. One staff member, PK Rangachari, has some very useful advice related to writing problems in his 'Writing Problems: A Personal Casebook'. This casebook discusses the many aspects of writing good quality problems and includes many examples drawn mainly from the biomedical, and biological sciences.
(http://www.fhs.mcmaster.ca/pbls)

The Maricopa Center for Learning and Instruction hosts a searchable database of links which is more useful than most as the search can be refined, so producing a sensible number of more relevant links.
(http://www.mcli.dist.maricopa.edu/pbl/problem.html)

Other useful sources of information

PossiBiLities; PBL in Physics and Astronomy, Raine D and Symons S, Higher Education Academy Physical Sciences Practice Guide, 2005 (www.heacademy.ac.uk/physsci).
Anyone interested in finding out more about the practicalities of problem-based learning should start with this publication, whether they are a physicist or not. It is full of sensible advice and good ideas and will be invaluable on the journey from devising problems, to training staff, to implementation and assessing student outcomes.

The Power of Problem-Based Learning: A Practical "How To" for Teaching Undergraduate Courses in Any Discipline, Duch B. J., Groh S. E., Allen D. E., (ed), Stylus , 2001.
Useful advice from various authors, many of whom are from a science background.

Foundations of Problem-based Learning, Savin-Baden M., Major C. H., Open University Press, 2004.
Explores the foundations of problem-based learning and its use. It includes discussion of academic development, cultural diversity, assessment, evaluation and curricular models.

Problem-based Learning in Higher Education: Untold Stories Savin-Baden, M. Open University Press, 2000.
Explores both the theory and the practice of problem-based learning and considers the implications of implementing problem-based learning.

Problem-based Learning Online, Savin-Baden M. and Wilkie K., Open University Press, 2006.
A collection of papers which explore the development of an online pedagogy for problem-based learning.

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