

Using a problem based learning approach to improve the teaching quality of *Analytical Chemistry*

Liu Yu

Chemistry Department
College of Science
Tianjin University
Tianjin 300072
People's Republic of China

Abstract

Problem based learning (PBL) is increasingly being used in many disciplines. It was shown that a problem based learning approach can produce students who are well-motivated, independent learners, effective problem solvers, and who have a broad range of interpersonal and professional skills. Based on the review of the current state of teaching in *Analytical Chemistry* in Tianjin University, this paper discusses how to use the PBL method to improve the teaching quality and some difficulties that can be anticipated during this modification.

Introduction

Problem based learning is learning that is driven by a problem, not by an abstract concept. Ideally the problem can be found in real life, and it has no quick, easy solution. Students not only have to solve the problem, but they also have to find the information and other resources they will need. They work in groups; they share information; they teach each other. They are engaged in active learning to develop and test their hypotheses so they can arrive at solutions to problems. The principles and concepts they learn along the way are an integral part of the problem with which they struggle. The knowledge they gather is connected to the course at hand, and they can integrate what they learn into other courses. Their grades are based not only on what they remember, but also on what they can do (Kuwana 1997).

The PBL method was developed in the west over the last 40 years. It has been shown that the PBL approach produces more motivated students with a deeper subject understanding, encourages independent and collaborative learning, develops higher order cognitive skills as well as a range of transferable skills including problem-solving, group working, critical analysis, lifelong learning and communication (Boud and Felletti 1998). Students should be required to develop a problem solving strategy, to acquire new knowledge and to make judgements, approximations and deal with omitted/excess information (Overton 2001).

PBL students perform as well as, or slightly worse, than students from traditional courses on conventional examinations of knowledge. However, PBL students are superior with respect to their approach to study and learning, long-term retention of knowledge, motivation, use of resources, key skills and subsequent success as postgraduates.

PBL methods should be used especially to teach analytical science, as:

1. Analytical chemistry can provide a rich source of contexts in, for example, forensic science, pharmaceuticals, environmental science, and industrial chemistry. The scope for producing 'real' problems for students to solve is great (Belt 2002). So it is relative easy to use PBL in teaching analytical chemistry.
2. When we use the traditional method to teach, we always face the following problems:
 - a. students don't know how to apply the analysis method they have learnt to solve a real problem, they cannot tackle unfamiliar and/or open-ended problems and thus, are unable to apply their chemical knowledge;
 - b. they don't know how to handle data and information; and
 - c. they don't know how to report the results.

The PBL method can solve these problems. So I have decided to use the PBL method to improve my teaching quality after I return to China.

PBL has been successfully applied in analytical chemistry in the west. For example, Simon West at the University of Plymouth has developed problem-

solving case studies as an approach to learning analytical chemistry (Belt 2002). Thomas Wenzel has used PBL to teach undergraduate analytical chemistry and associated laboratory experiments successfully (Wenzel 1995, 1998), and Ken Hughes has used PBL in an introductory analytical course (Hughes 1993). These successful examples show that using PBL, students are more fully engaged in the learning process and their understanding of the process of analysis is increased. In other words, the PBL method is better than the traditional one.

Description of this course

Analytical Chemistry is a course for second year undergraduate students majoring in applied chemistry, chemical engineering, and material science at Tianjin University of China. Usually, it involves 40 hours lectures and 32 hours laboratory work.

The main course objectives are to let students:

1. gain a deeper understanding of the principles, including: sampling, sample preparation, separation science, classical techniques, instrumental techniques involving molecular and atomic spectroscopy, chromatography, electrochemistry and quality assurance;
2. gain technical analytical chemistry skills and generic skills; and
3. help students develop a deeper understanding and appreciation of science.

Current teaching methods

Recently, we have been striving to focus more of our teaching on the students' activity, but the teaching strategies used currently are mainly teacher-centred: students listen to a teacher, work standard problems, and memorise facts for examinations. College students spend little time understanding the concepts behind the material. They work alone, and their achievement is based on routine paperwork, namely examinations and assignments. In the end, although students can get high scores in the final test, they may not (and see no incentive to) retain new information long enough to apply it to subsequent courses. They don't know how to interpret the data and they don't know which method they should choose to solve real-world problems.

Modification of the course

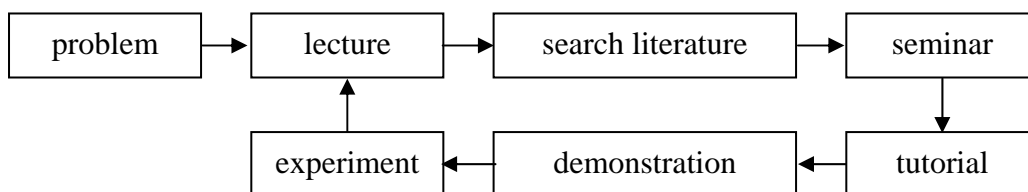
We need to change our teaching approaches to overcome the deficiencies in the current teaching strategy. The goals of our modifications are to give students an active learning context, help students to take a deep level approach to their learning; and train students to become more independent, lifelong active learners. At the University of Sydney, we have learnt a number ways in which we can teach science to encourage the development of deep learning strategies in our students. The PBL method is an excellent one.

I have designed four problems for use in this course. These problems can cover most of the content of the course including High Performance Liquid Chromatography (HPLC), Gas Chromatography and Mass Spectrometry (GC/MS), atomic absorption, ion chromatography, Ultraviolet and Visible Light (UV-Vis) and Fourier Transform Infrared (FT-IR) spectroscopy (Table 1).

Table 1. The problems and contents of analytical chemistry

Problem	Content
What components are included in a soft drink?	Sampling, sample preparation, Ultraviolet (UV), Liquid Chromatography (LC), Capillary Electrophoresis (CE), interpret data
What pollutes seawater? What components are found in sea water?	Sampling, preparation, Atomic Absorption Spectroscopy (AAS), Atomic Emission Spectroscopy (AES), ion-selectivity electrode, titration, gravimetric analysis, interpret data
How can we detect doping?	Sampling, sample preparation, GC/MS, Isotope Ratio Mass Spectrometry (IRMS), interpret data
Why did the European Union reject our tea shipments last year?	Sampling, sample preparation, AAS, AES, GC/MS, interpret data

The generic teaching process will use the following procedure:



Problem

During the first class session the students are divided into four-member teams and presented with the problem by video. For example, the analysis of doping:

In 2008, Beijing will host the Olympic Games. In order to assure the fairness of the competition, we should set up a doping-detection laboratory. When you graduate, you might find a job working in this laboratory. But how would you detect prohibited drug use?

The video can be used to illustrate a scenario in which some athletes die suddenly during the competition because they took an illegal sports drug. A video about the side effects of the sports drug including liver and kidney ailments, reproductive problems in women and the growth of breasts in men can also be shown. The objective of using the video is to stimulate the interest of the student and to emphasise the significance and necessity of detecting sports drugs. The students would also be given an assignment in which they are asked to find out what the sports drug is, how many kinds of sports drugs an athlete might take, and other background information.

Lecture

During the lecture section, the students will be taught the basic principles of analytical methods, for example, in the case of doping-detection, the lectures will cover basic principles of chromatography and MS. The students will also receive an introduction to the use of the Internet and library to find relevant materials. Although students are familiar with the Internet, they are not proficient at accessing and critically evaluating databases and other information useful to chemists.

Search the literature

Outside the classroom, students will use the library and Internet to search for resources.

Seminar

During the seminar section, the students share the information they found, discuss the problem and exchange their ideas. Using the newly acquired information they work towards a solution to the problem.

Tutorial

If the students have some questions, they can ask the teacher during the tutorial section. The tutor's role is one of observation, guidance and support. After the students devise a solution, they can prepare to do the experiments.

Demonstration

Before the students do the experiments, teachers can use the demonstration to teach students how to operate the instruments, and tell them which aspects to pay more attention to.

Experiment

Students get data through the experiment, and interpret the results by themselves. Finally they will submit a written report. The laboratory course emphasises problem-solving and technical skills.

If the students cannot get the right answer, they can repeat this procedure. This cycle of independent study, group interaction and critical analysis may be repeated as many times as dictated by the problem.

Assessment

As PBL differs from traditional methods in many aspects, it may not be appropriate to assess students in a traditional way. The assessment should be matched to the desired learning outcomes. According to recent research on the effect of assessment on learning approach, assessment

methods will significantly influence the learning approach (Scouller 1998). In order to encourage active learning, I will use a combined assessment to evaluate the learning outcome of the students (Table 2). The assessment will include five parts:

1. formal written examination: used for assessment of basic knowledge outcomes;
2. assignments: used as feedback on the learning result;
3. workshop performance: reflects students' learning attitude;
4. laboratory work reports: act as a feedback on practical activities; and
5. oral presentation: reflects the presentation skills and communication skills they acquired.

Table 2. Example assessment schemes

Written examination	30%
Assignments	10%
Workshop performance	30%
Experiment report	15%
Oral presentation	15%
Total	100%

Assessment may focus on the solution to the problem, or the problem solving process or the skills development aspect. Students may be involved in assessing each other's contribution to the activity or may be involved in self-assessment and reflection.

Anticipated difficulties

The PBL method is a relative new concept in China. One can confidently anticipate several difficulties when implementing this method of teaching.

Time

PBL may be a new experience for staff and students. We need time to develop and test problems, to train staff and to tutor the students. PBL takes more staff time than traditional methods because the group sizes have to be restricted. A PBL session with 200 students in a lecture theatre doesn't work! Many institutions may be short of the sort of space that helps PBL work well – flat seminar rooms with movable furniture. Time spent in both the lecture and the laboratory is critical to the learning process and to student progress in areas of problem-solving and communication. The current trend is to decrease the time spent in the laboratory and the lecture. However three hours of laboratories and two hours of lectures per week do not adequately educate or train students headed for the work force.

Students

In China, the number of students is very large, and the number of teachers is relatively small. So it is hard to teach students in small classes. The students have become accustomed to studying passively and individually. They don't know how to cooperate and communicate in a group. Any frustration will make them give up trying the new method. The goal of most students is to pass the entrance examination to graduate school. They care more about the

score than the abilities. The PBL method cannot assure them that they will get a high score, so they may be reluctant to change their study style. Without the cooperation of the students, it will be hard to implement the modification.

Money

In the PBL study, students are required to operate the instrument by themselves. They need to have ready access to any relevant resources in the library, Internet, etc. In order to meet this requirement, we need much more money for new instruments, hardware, software, and internet access. We also need money to pay for the teachers' extra work.

Staff

Teachers have no time and energy to do both teaching and research very well. Currently most Chinese teachers prefer doing their research work to teaching. This is because the publication and the project are the criteria for promotion. In this situation, finding a collaborator to implement the reform will be difficult. However, this reform is a large project, requiring the participation of many teachers. Support from the university is also needed.

Teaching reform is a long-term and complex task. It needs our enthusiasm and unremitting efforts. Certainly I will meet many difficulties that cannot be anticipated. So long as I have confidence, implement the modifications determinedly, and prepare adequately, success must follow.

Conclusion

PBL is a wonderful way of teaching. I believe that it will be possible and achievable to improve the quality of teaching by using PBL in my future teaching. But we can't expect to use PBL all the time and in every aspect of the teaching

process, because time is limited and the volume of material the students should learn is very large.

Acknowledgements

I would like to acknowledge the support of the China Scholarship Council, the University of Sydney, Faculty of Education, Faculty of Science and School of Chemistry. Many thanks to the following colleagues who helped me: Associate Professor Mike King, Associate Professor Mary Peat, Associate Professor Tony Masters, Dr Siegbert Schmid and other staff working in the program.

References

- Belt, S.T. and Evans, E.H. (2002) A problem based learning approach to analytical and applied chemistry. *University Chemistry Education*, **6**, 65-72.
- Hughes, K.D. (1993) Marine microcosm – using an aquarium to teach undergraduate analytical chemistry. *Analytical Chemistry*, **65**, 883A-889A.
- Kuwana, T. (1997) *Curriculum Developments in the Analytical Sciences*. <http://www.chem.ku.edu/Tkuwana/CurriculumDevelopment/>.
- Overton, T.L. (2001) *Problem based learning: An introduction*, LTSN Physical Sciences Primer 4, version 1, <http://dbweb.liv.ac.uk/ltsnpsc/primers/intrpbl4.htm>.
- Scouller, K. (1998) The influence of assessment method on students' learning approaches: multiple choice question examination versus assignment essay. *Higher Education*, **35**, 453-472.
- Wenzel, T.J. (1995) A new approach to undergraduate analytical chemistry. *Analytical Chemistry*, **67**, 470A-475A.
- Wenzel, T.J. (1998) Cooperative group learning in undergraduate analytical chemistry. *Analytical Chemistry*, **70**(23), 790A-795A.