

Using problem-based teaching and problem-based learning to improve the teaching of electrochemistry

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Abstract

Based on an analysis of current teaching approaches, a modified teaching and learning approach has been suggested for the teaching of electrochemistry at the University of Petroleum. The new teaching and learning process is guided by a pollution-related real life problem and such a process displays a mixture of characteristics of problem-based teaching and learning strategies. After inspecting the background theory of problem solving, and the requirements of our course syllabus, the author believes this project can meet the demands of the course.

Introduction

Since we are entering a stage of the knowledge explosion, higher education has to face a situation that, in the current time, universities or colleges are unlikely to be able to teach within a four year period all the essential knowledge a student needs for their whole career. That means the students have to master a self-learning method and a set of lifelong learning skills in order to meet the demands of the remainder of their professional lives.

The knowledge base of all disciplines has extended greatly in recent years and the power of human cognition has been enhanced dramatically. This new world needs more creative scientists to explore unknown areas and reconstruct its knowledge structure in line with contemporary developments.

Research has revealed that human and individual learning approaches and knowledge construction are related to personal experience and pre-learned knowledge (Entwistle 1998). So when a new concept is introduced into someone's mind, everyone has his/her unique way of adding this new idea into their original concept scheme and thus everyone can be said to learn in a different way.

The demand to establish a higher quality of student learning in the tertiary sector is synonymous with the acquisition of a deep level approach to understanding amongst our students. However, recent research concluded that traditional teacher-centred learning models are more likely to result in surface level learning. Additionally, research indicates that higher quality learning is more likely to come from a more student-centred approach to study (Entwistle 1998).

Current teaching process reconsideration

Chemistry education in China is carried out mostly by a teacher-centred model. But teaching model changes must be based on a cautious approach which includes student surveys and careful programming and testing. The project outlined here would be one proposal for implementing program change.

Electrochemistry is normally a part of physical chemistry in China and it is usually carried out at 3rd year undergraduate level. Ordinarily, the teaching component of the course lasts for about 14-15 hours. The content of this part of the course consists of theories of electrolyte solution, equilibrium of chemical reaction in cells and the basic behaviour of working cells. To supplement the course teaching program, 2 or 3 related experiments are provided during this period.

From the whole teaching process as shown in Table 1 it can be seen that lectures have been divided into six sessions and each section focuses on one or two special academic topics. During the whole teaching process, a specific knowledge construction has been established bit by bit. In a typical teacher-centred model, the teaching process places its emphasis on the integration of academic knowledge. At this point, lectures are located at the centre of the education process. Tutorials,

inquiries and laboratory work are served up as support for knowledge construction. The knowledge establishment process can be described as Figure 1.

The course assessment mark is composed of an examination, assignments and practice reports, but the examination mark contributes the majority weight.

Lectures	Tutorials	Inquiries	Laboratory work
Motion of ions in solution		2-3 hours per week, regularly	2-3 practices, each lasting 3-4 hours.
The thermodynamics of ions in solution			
The thermodynamics of cells			
Equilibrium of electrochemical reaction	Applications of standard potential/problem solving training		
Half-reactions and cell reactions			
Basic behaviors of working cells			
Total: 12 hours (In-course)	2 hours (In-course)	Out-course	
Assessments			
Examination/assignments			Report

Table 1. The current teaching strategies

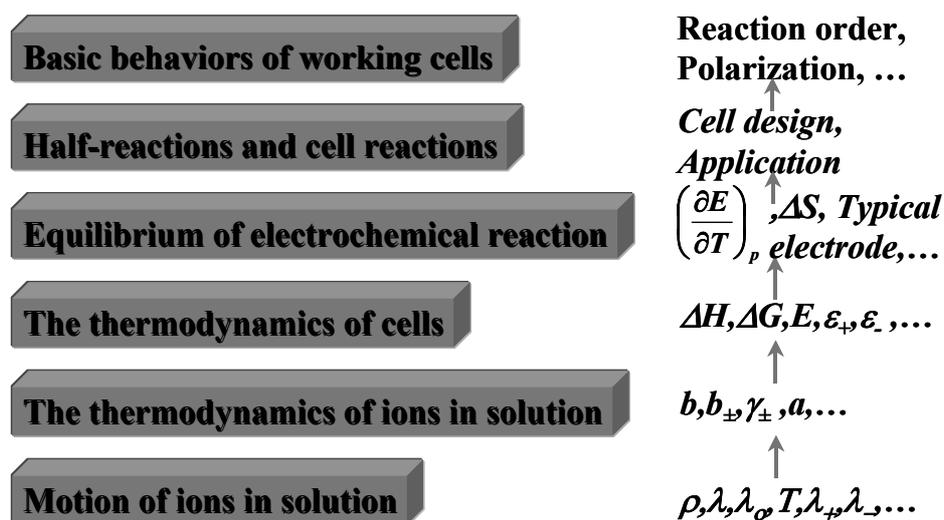


Figure 1. Knowledge construction within the course

Questions from recent processes

The impression is that such a teaching and learning approach gives us is a typical teacher-centred model. Most of the effort is spent on exploring the theoretical equilibrium situation but just a few hours in exploring the application of the theories. The purpose of this process is to make students master some important theories of equilibrium electrochemistry by lectures, to understand some basic skills of electrochemistry measurements by laboratory practices, and to know some applications of electrochemical theories. The process also intends that students will gain some essential abilities of analysis and research on ideal cells after their learning experiences.

However, because such a teaching process places strong emphasis on introducing theories and significantly less in training students in solving real problems, the students may sometimes come to feel that the learning process is boring

and find it difficult when they try to use their learning outcomes to solve a real world problem. It is also the case that students are not aware of the problems from which these theories have been developed. Students are always confused by ‘why we need to learn these theories?’ and ‘how to use the theories we learn to solve real problems?’ Moreover, the examination mainly asks students to exercise their memories about their learning, so the learning process may just be a process of taking notes while attending a class and writing down these notes from memory during the examination. After the examination, some or even most of their learning outcomes are likely to be thrown away or simply forgotten, as they hold little direct relevance to the student’s own world.

To solve these problems, teachers must give students an explicit learning purpose while the course is taking place and the most important way of doing this is to develop a bridge between text based knowledge and the real world.

Moving from teacher-centred to student-centred model – some successful prior works

Based on the analysis mentioned above, a conclusion may be drawn that we need to change our teaching approach from a teacher-centred model to a more student-centred one in order to encourage our students to adopt a deep level approach to their learning, and to encourage them to master a competence in problem solving. From this point of view, some prior work has given us many good examples of how to focus students' interest into course learning and help them gain a greater personal problem solving competence while learning.

The case study is a strategy used for motivating learning interest in specific courses or sessions by using a real world story, which relates to the content of that learning and which can give it relevance and meaning. As prior work has shown, case studies can work successfully, and additionally they can induce students to give more consideration to real world problems and thus encourage student to work with a deeper level of understanding (Challen and Brazdil 1996; Doyle, Gatzke and Parker 1998).

Problem-based learning (PBL) places greater emphasis on student's self-directed learning and training students' research ability while learning. In PBL, a real world problem has been used as a guide to focus students' learning interest and it will usually cover most of the course knowledge (University of Leicester 2002). So while students work at solving this problem, they are likely to have acquired most of the knowledge that the discipline covers and, furthermore, some students may have learned more deeply in some aspects of the field. Traditionally this kind of strategy is just used in postgraduate teaching or senior undergraduate teaching while the students work on research projects. Recent research has shown that this kind of strategy can also work well in supporting discipline teaching with undergraduate students. This prior work has given us some examples of successful cases and the surveys have also shown that most students like learning using such an approach.

Another powerful method that has been widely used is concept mapping, which was developed by Professor Joseph D. Novak at Cornell University in the 1960s. Concept mapping stresses the importance of prior knowledge in being able to learn new concepts (Thomas and Schwenz 1998). In some points of view, this strategy is not only a learning strategy, but also a useful method for teachers to organise their teaching materials.

Modifications in teaching and learning approach

To stimulate students' learning interests and let students know how to use their learning to solve a real problem, and also to meet the demands of the discipline and fulfil the course syllabus, some changes need to be made. They are: using a real problem to guide the teaching and learning in

electrochemistry in order to stimulate the students' learning interests; giving lectures to establish a basic knowledge structure of electrochemistry; setting some relevant laboratory work for students to master the elemental skills of practical working competences; using tutorials and workshops to help students practise their problem solving skills; and training students to work in teams, and finally, using a combined method of formatting and judgement to encourage students' learning and to provide a vehicle for assessment.

A PBT/PBL problem: how to reduce the emission of vehicles – electricity power is a proper solution?

A course-based problem should be: real; of wide concern; and discipline related. Considering the level of air pollution of some metropolitan cities in China, the exhaust gasses produced by vehicles has now become one of the hottest topics in the public domain and has caused much discussion both in public and government arenas. So a problem related to this field may cause significant interest and stimulate students' into learning more actively.

The planned teaching and learning approach will be based on a problem of 'How to reduce the emission of vehicles – electricity power is a proper solution?'. Addressing such a problem requires a wide background of knowledge, some scientific proposals for solving the problem may be based on knowledge beyond electrochemistry, some subsequent exploration must be used to focus students' attention into specific areas and fields. To help students solve the problem step by step, some carefully selected and relevant questions may be used to guide the problem solving process, giving essential clues to students in order to lead to deeper thinking on the problem, and direct student's learning to specific areas.

So after the main problem has been put forward, four additional questions must be added for explicating the specific task.

1. What cause the emission problem of vehicles?
2. What are the possible proposals for solving the problems?
3. Within an electrochemistry or thermochemistry engine, which one is the more effective approach to energy transformation?
4. How does a chemical reaction happen in an electrochemical cell?

Here the first question functions to force students to explore background knowledge in the topic and help them understand what is the root cause of the problem.

The purpose of second question is to let students search out possible solutions, thus they will gain a wider perspective on the problem and encourage them to think more independently and creatively. Within the process they may develop a real experience of how to find their own solutions and this may help them when they have to solve problems in the future.

By asking the third question, the attention of the students will be focused on the field of electrochemistry and students will be introduced to electrochemical perspectives. To answer this question, they must understand the definition of energy transformation and how to calculate the efficiency of this process, in which almost all the thermodynamic knowledge will be imbedded.

The last question requires students to understand how a chemical reaction happens in an electrochemical cell. This is important because that is directly related to issues of how to turn a theoretical idea into a practical reality. In principle, every chemical reaction can happen in a cell, but when we try to make such a process possible, we must find a specific way to work a specific cell. There is much basic knowledge and many design skills associated with this process.

After all four questions have been properly addressed, the solution of the main problem solving task will be concluded naturally. Such a problem solving approach is not only a knowledge gaining process, but will also teach students how to divide a real problem into a set of smaller ones and then solve them one-by-one.

Does the problem cover all knowledge of electrochemistry?

Because the whole teaching and learning process has been driven by a main problem, before this proposal is performed, some question and issues must be checked out carefully to ensure this process will be effective. Consideration must be given to two different aspects: whether it covers all area of the knowledge of the discipline which is required by the syllabus; and whether the discipline itself can provide enough knowledge for students to solve the problem.

As a suggestion, the whole teaching and learning process will be divided into several parts such as lectures, workshops, tutorials and practical sessions. Each part functions differently and performs a different duty in the process: lectures to convey knowledge; workshops for discussing and enlightening creative thinking of problem solving; tutorials for practical knowledge and showing application of basic principles; and laboratory work for training manual skills and understanding essential operations for electrochemistry research.

Lectures will be divided into five sessions, each session will focus on one or two special topics. Combining topics will set up an entire knowledge construction. As shown in Figure 2, these five sessions become knowledge supporting the problem solving.

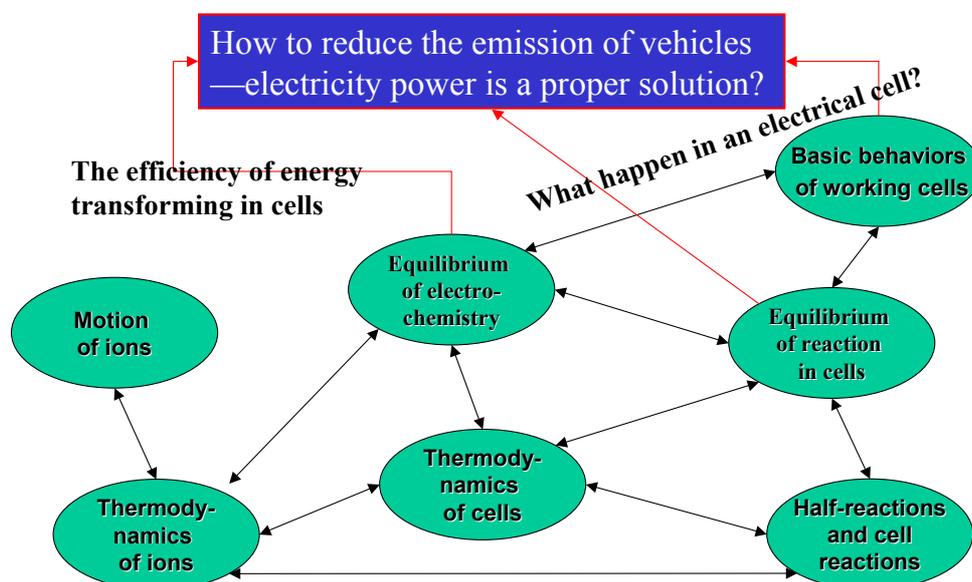


Figure 2. The scaffolding of the problem solving

Summarising the teaching and learning approach

In order to execute the teaching process more smoothly, the following sequence of teaching events is suggested.

1. Workshop: problem introduction
In this session, a problem case should be introduced and students will act as an official consultative expert to find a solution. After that, students will be divided into

groups of four or five members to discuss the problem of 'what causes the emission problem?' and try to find any possible reasons. At the end of the session, each group will be invited to give their results and the teacher will summarize their results. Furthermore, a teacher should guide the topic into electrochemical field.

2. Lecture: motion of ions in solution
3. Tutorial: measurement of ion conductivity

These two sessions give students some basic background knowledge of electrochemistry and some additional examples are also given for students to understand how these theories work in real cases.

4. Lecture: thermodynamics of ions in solution
5. Lecture: equilibrium of electrochemical reaction
6. Lecture: thermodynamics of cells
7. Tutorial: chemical reaction in cells and discussion: efficiency of energy transformation
These lectures will give students some basic knowledge of equilibrium of electrochemical reactions, a tutorial will be given to show examples of how to use this knowledge to determine the efficiency of energy transformation in cells, and students will be asked to review some relevant content on thermodynamics to determine the efficiency in thermoengines.
8. Lecture: half-reactions and cell reactions
Some typical half-cell or electrode reactions will be introduced in this session to help students gain essential knowledge to understand future sessions.
9. Tutorial: cell design introducing some contemporary battery cells, working principles and characteristics
10. Tutorial: significant facts of working cells

After this, students should have accumulated sufficient knowledge to solve the main problem. Students will be asked to give a report on 'how to reduce the emission of vehicles?' individually and presenting a problem solving presentation based on their group work.

Three supplemental laboratory practical sessions will be given during the learning process for students to master some elemental methods of measuring and of operating skills in electrochemistry. Some important concepts will also be learned during these practical sessions.

1. Thermochemical measurement of cells
Some typical electrodes and their reactions and the concept of a salt bridge will be learned in this practical activity.
2. Thermochemistry measurement of cells
The selectivity of reaction at an electrode, current efficiency and quantity of electric charge will be covered in this practical.
3. Dynamic measurement of a working cell
A typical hydrogen electrode will be introduced in this practical activity for students to be familiar with a frequently used method in studying the electrochemical behaviour of a working cell, such as voltammetry measurement and the concept of the Tafel equation will also be introduced.

A whole teaching and learning approach can be summarized as Table 2 shows.

PBT/PBL	How to reduce the emissions of vehicles?		
Lectures	Tutorials /workshop	Laboratory work	Inquiries
Motion of ions in solution	Discussing: possible proposals	3-4 practical sessions each lasting 3-4 hours	2-3 hours per week, regularly
The thermodynamics of ions in solution	Measurement of ion conductivity		
The thermodynamics of cells	Chemical reaction in cells		
Equilibrium of electrochemical reaction	Application of E^0 , ε^0		
Half- reactions and cell reactions	Significant facts of working cells		
Total: 10 hours (in-course)	5 hours (in-course)		Out-course
Assessment			
Examination/Assignments	Workshop works	Reports	

Table 2. Summarizing the teaching/learning approach

Teaching and learning approach – assessment

According to recent research on inferences of assessment to learning approach, assessment methods will significantly influence the learning approach (Scouller 1998). In order to encourage active learning, a combined assessment will be used for marking students' learning outcomes. The weighted marks will be consist of five parts: a formal written examination will be used for assessment of basic knowledge outcomes; marks from assignments will be used as feedback on the learning approach; workshop performance will reflect students' learning attitude; laboratory work reports will act as a feedback on practical activities; and the problem solving proposal and

performance at the presentation will furnish the PBL outcomes.

Conclusion

This modified learning and teaching approach has some significant differences from the original teaching approach. It will have the characteristics of a more highly student motivated focus, and will give students specific and explicit end. It emphasizing group cooperation in learning and will encourage students' self-orientated learning. It is a problem-orientated learning, problem solving approach by which students can not only get basic knowledge while learning, but can also experience how to use their knowledge to solve a real problem. There is a combined

assessment strategy which not only addresses a students' final examination mark but also addresses student performance the while learning.

Although a problem-based teaching and learning process can stimulate students' learning interest, some important facts still must be noted.

1. Guide students from main problem into electrochemistry field

The problem guiding electrochemistry learning is an open problem. Solving solutions can come not only from electrochemical field, but also from other fields. While consequent questions have been used for introducing learning interest into electrochemistry, students must understand it doesn't mean that correct answers cannot be found from other fields.

2. Find relevant examples for using in workshops

Because a learning and problem solving process is a difficult process, especially for weaker students, the teacher must take every opportunity to help students solve the problems they encounter. When the teacher selects examples for using in lectures, tutorial and workshops, they need to choose relevant problems in order to help students know more directly how to apply the theories they have learned to real life instances and cases.

3. Students don't know how to learn by themselves

Some students may not be used to self-directed learning, so those students must be added to a group composed of students who do have these skills to some degree, so that they may get help from others and find it easier to succeed.

4. Students may not get as good marks as with traditional teaching

In a traditional teaching and learning approach, teachers controlled the learning process. So students may have perform better in formal examinations, although they may have weaker competence when they solve a real problem. This situation has changed much in recent years, but only if a new teaching and learning strategy can produce as good a mark in a comparable examination will it be possible to convince others. So while such a learning approach is

carried on, teachers must carefully consider how to ensure that their students give a good performance in written examinations. At the same time, problem solving performance must be considered in the course mark as an important factor.

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