Edutainment in the *Chemistry of Fine Chemicals*

Shimei Xu
College of Chemistry and Chemical Engineering
Xinjiang University
Urumqi
Xinjiang 830046
People's Republic of China

xushmei@hotmail.com

Abstract

Incorporating some forms of active learning, such as problem based learning (PBL), role playing, and interactive lecture demonstration (ILD), into the traditional teaching style is meant to create fun and an enjoyable experience in the learning process. Moreover, a workshop tutorial is added to capture student interest and enhance student motivation and self-confidence. The corresponding assessment system is reformed to assess the long life learning skills in a diverse and enjoyable form.

Introduction

In recent years, much attention has been given to the effectiveness of active teaching strategies. This discussion forced the education community, especially in higher education, to realise that traditional teaching methods failed to cultivate the students' longlife learning skills (Jackson and Walters 2000), such as cooperative skills, communication skills, and leadership skills. To cater to the demand for cultivating 21st century skills, some new teaching methodologies are applied to provide training in these skills. However, many relevant documents only focus on the methodologies themselves, and ignore the target audience—students. As a result, students do not accept and enjoy these methods completely. In addition, there are some potential barriers inherent in the employment of the methods, so most chemistry students continue to be taught in lectures, despite considerable evidence that traditional approaches are ineffective in teaching these skills.

A Chinese proverb on education says, 'tell me, and I will forget; show me, I may remember; involve me, and I will understand'. What should be done to get students involved? I think an effective method is to stimulate students' interest. It has been found that when students are interested in the topic or material, they are more likely to understand the lessons and key points (McKeachie 1994).

This paper will discuss possible contemporary teaching strategies used to stimulate student's interest and let them acquire the knowledge whilst having fun in an enjoyable learning environment.

Discussion

Description of the course
The *Chemistry of Fine Chemicals* is a branch of applied chemistry. The content is closely relevant to everyday life. Generally, the course can be divided into three parts: polymer fine chemicals including adhesives, paints and functional polymers; organic chemistry of dyes, surfactants and detergents, food additives and so on; inorganic chemistry including fine pottery. The course focuses on the principle and tactics used in the synthesis of fine chemicals, as well as the application of these chemicals. In terms of the content, students probably engage their interest in the course because of its close connection to real world.

Description of the target audience
This course is delivered to the 3rd year students who major in applied chemistry. After two years of study, students have learned fundamental chemistry: inorganic chemistry, organic chemistry, analytical chemistry and physical chemistry. Moreover, the students will enter the laboratory and do research work in their fourth year. So the course should be given based on their background knowledge, as well as preparing them for the demands of research.

In this age of information literacy, one essential goal of education must be to encourage the student to develop lifelong learning skills rather than just acquiring knowledge. To stimulate the interest of students on the course, I propose to apply some new teaching methods in the lecture. In addition, a

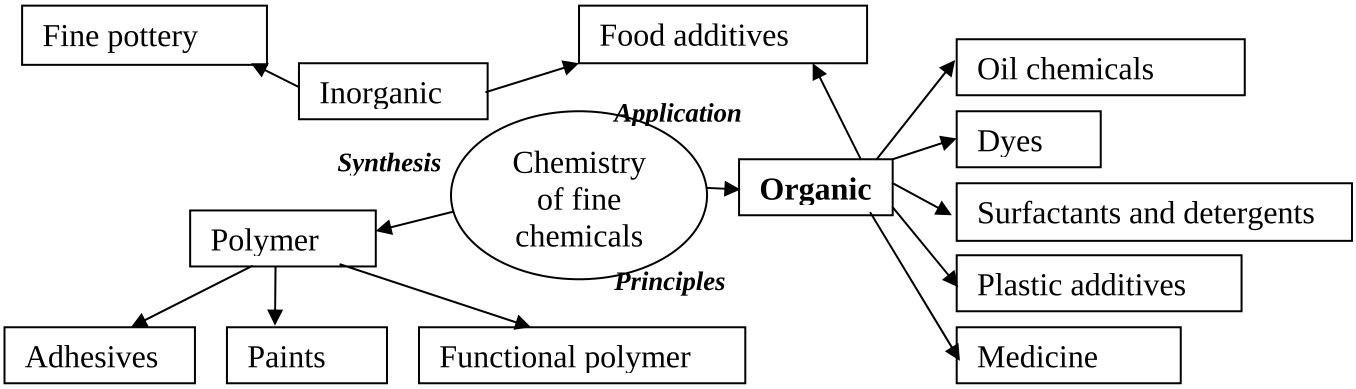

Figure 1. Course map

'Workshop Tutorial' will be introduced and the assessment system reformed to reflect these changes.

Lectures

It is widely understood that straight lecturing is relatively ineffective when compared with interactive learning techniques such as problem based learning, role playing and interactive lecture demonstration.

Problem based learning

Problem based learning (PBL) is an instructional process characterised by the use of 'real-world' problems as a context for students to learn problem-solving skills and acquire the prescribed knowledge. It can enhance students' achievement of communication skills, leadership skills, cooperative skills, creative and critical thought, and team collaboration (Stahl 1998).

The chapter 'functional polymers' is a very important chapter in this course, also a hot topic in research. Considering the content of this chapter, as well as the characteristic of PBL, I intend to apply PBL in this chapter.

I will construct a problem such as:
A soil improvement reagent, called 'solid water', is used by farmers to improve the growth of plants in dry regions. The reagent has a distinguishing characteristic: it can absorb hundreds, even thousands, times its weight of water. Moreover, it does not release the water even under pressure. In fact, it is a polymer. During the usage of this material, the farmers find its capacity decreases dramatically when in saline solution. So the problem is, what is solid water? How can its salt-tolerance be improved?

I will give students some hints if they have still no ideas after preliminary research, such as ionic superabsorbent resins, hydrogels and graft copolymers. Of course, the problem is open-ended, so the students will find more than one solution for the problem.

Role play

Compared with PBL, role play is more interesting. Role play is where an individual, playing themselves or someone else, is placed in a given situation, and enacts how that person would behave as a result of what is going on around them (Sutcliffe 2002). There are two different kinds of role play. One kind involves having students act as if they were components of a system. For example, two students act as hydrophilic functional groups such as carboxylic groups in an absorbent resin modelled by several students forming a chain hand in hand. When a water molecule comes along, the two students separate, and then absorb the water into the network. Such a process demonstrates the absorbent mechanism.

The other kind of role play involves an ethical issue. Students act as humans in a situation where a decision must be made. I will use it in the chapter 'surfactants and detergents'. Students are divided into different groups, each group between 6 and 8 students. They will deal with a problem about designing a novel detergent. One group acts as chemists. The chemist will be devoted to inventing a magic, special-function detergent. Another group will act as a factory, which concentrates on the cost and manufacture process of the detergents. Another group will act as customers. The customer hopes the detergent will be of low price and good quality. Moreover, it should be harmless to the health. The others will act as environmentalists, who will emphasise a 'green' detergent. It cannot cause environmental pollution. By role play exercises, students need to do some research to make decisions, debate with each other, which will result in a deep level learning.

Interactive lecture demonstration

Chemistry is a special subject. It needs experiments and demonstrations to illustrate and test the theory. In the interactive lecture demonstration, one sets up a demonstration, and asks the students to predict and write down, with consultation among themselves, their prediction of the outcome of the demonstration. One then carries out the demonstration, discusses the results and presents the relevant theory. The idea is to engage the students, elicit a commitment to a position, confront this with reality, and use this event to trigger reflection and foster understanding, which engages students in the learning process and, therefore, converts the usually passive lecture environment to a more active one (Sokoloff 1994). For examples, in the dyes chapter, I start with the animation demonstrations to convince students that the colour of dyes is relevant to the structure. Then solidify students understanding of the principles by more complex demonstrations.

Tutorials

In the past, there were no tutorials available in this course. Previously, I spent several minutes on tutoring the assignment at the beginning of a lecture. However, considering the aim of the course, the concentration of instruction should not be put on how to guide students to finish the assignment. The workshop tutorials use demonstrations and probing questions to facilitate conceptual change and support learning processes. This allows students to openly discuss and work on problems, to explore different avenues of solution without feeling that there was one correct solution, which must be marked. (Sharma 1999). Some problems can be designed like this: Diphenylamine dye is a type of toxic black direct dye. It has distinguishing fastness and low cost. However, in recent years, it has been found to cause cancer. How could the dye be replaced? The requirements are to keep both its excellent dye fastness and low cost, of course after modification, it must still be black!

In the assessment

As the teaching methods are changed, a change in the assessment system should follow. Traditional assessment methods, such as quizzes or final examinations, develop students' memories, but not in a creative, innovative way. In the past, I tried knowledge competitions to evaluate the prompt response ability and cooperative skills. The results showed that students were very enthusiastic about this approach. Other assessments, such as topic contests and student presentations can evaluate the outcome in an enjoyable atmosphere.

Of course, the possible problems and potential barriers must be considered. For example, these methods are a big change for both students and teachers and most of them are time-consuming. Although traditional teacher-oriented methods were relentlessly passive, the learning process was comfortable, and safe. So students are used to a traditional style. They will feel uncomfortable and stressed in the face of new teaching methods. So I intend to start with a little change, then increment change step-by-step, not overnight. Moreover, I will combine the contemporary teaching methodology with traditional methods before students accept it completely.

Conclusion

For successful education, theories of instruction are intricately related to theories of learning. The setup of teaching strategies should base on stimulating student's interest. Only when students show their interest on a course, are they liable to become involve in it. Therefore, they will acquire the knowledge in a deep level and become a real lifelong learner.

Acknowledgement

I would like to thank the Chinese Scholarship Council and Xinjiang University for selecting me and giving me such a good opportunity to study here. I wish to thank Cecilia Goon and David Medhurst for their kind help on my English language studying. Many thanks to Mike King and Mary Peat for their wonderful lectures on contemporary teaching methods. Their patience and encourage are appreciated. Sincere thanks to Tony Masters for his generous help throughout the studying process in the School of Chemistry. Also thanks Siegbert Schmid. Thanks to my classmates. Their companionship makes the process full of happiness.

References

Jackson, P.T. and Walters, J.P. (2000) Role-playing in analytical chemistry: the alumni speak. *Journal of Chemical Education*, **77**(8), 1019.

McKeachie, W.J. (1994) *Teaching Tips: Strategies, Research, and Theory for College and University Teachers*, Houghton Mifflin Company, Boston.

Sharma, M.D., Millar, R. and Seth, S. (1999) Workshop tutorials: Accommodating student centred learning in large first year university physics course. *International Journal of Science Education*, **21**, 839-853.

Sokoloff, D.R. and Thornton, R.K. (1997) Using Interactive Lecture Demonstrations to Create an Active Learning Environment. *The Physics Teacher*, **35**(6), 340.

Stahl, F.A (1998) *Student-Active Science: Models of Innovation in College Science Teaching*. Philadelphia, Pennsylvania: Saunders College Publishing.

Sutcliffe, M. (2002) *Using role-play to teach undergraduate business students: challenging the teacher, supporting the learner*. Business Education Support Team Conference Paper, 4.

Using contemporary education strategies to improve teaching and learning in *General Chemistry*

Wang Xiaojie
School of Chemistry
The National University of Defence Technology
Changsha
Hunan province
People's Republic of China
410073

yj605@sina.com

Abstract

Based on an analysis of the background, some problems have been identified in the teaching and learning of *General Chemistry*. Contemporary education strategies are used to solve these problems. Strategies which can be practised immediately are discussed. Three approaches are considered in this paper: case studies, concept mapping and problem based learning. Building up a Virtual Learning Environment to encourage online learning is expounded at the end of the article as an area that needs more research work before implementation.

Background

Description of the course
General Chemistry is a common fundamental course to all the students who are not majoring in chemistry in the National University of Defence Technology. The aim of this course is to ensure that students gain a wide knowledge of all areas of our disciplines at a higher education level.

Today, science and technology has penetrated through all aspects of our modern society. Chemistry as a central science has become more and more important. Although almost all the students who are undertaking this course will never become a chemist, it is essential for all the undergraduate students to grasp some knowledge of chemistry. This is one of the strategies that can help students develop a science-oriented basis for making future decisions. It can enhance their comprehensive ability of problem solving.

Current teaching approaches
As a common course supplied for all the university, *General Chemistry* is considered important and has been undergoing reform for several years. Some measures have been taken with the course, such as using the new textbook; applying computer aided instruction (CAI) to improve teaching efficiency; developing a web site to encourage online learning.

Although some changes have been introduced to this course, the main method of teaching is still the lecture. Students do not spend much time studying independently, but rather spend their time listening to lectures and taking notes. There are seldom tutorials and no seminars. Outside the lecture, students are only required to complete assignments. At the end of the semester, they have to pass the final examination.

Problems encountered

According the aim of this course, the most important aspect of this course is increasing students' interest in the course and making them more active learners.

All the changes to the course have significantly improved the teaching and learning, however these changes are not enough. Some important features of student-centred strategies have not been achieved. In particular the traditional teaching strategies, which do not encourage problem solving ability and creativity, result in students seeing the course as boring.

It is vital and necessary to further and significantly reform the structure and teaching style of the course.

Modifications of teaching and learning in *General Chemistry*

There are many things that can be done immediately to improve the teaching and learning in *General Chemistry*.

Redesign the contents

The main concepts and theories that should be taught to students have been fixed by the syllabus, but the details are flexible. A good design of content can promote the student's interest greatly.

Many concepts and theories in *General Chemistry* have been developed decades or even hundreds of years ago. The students often don't treat them as science, but as history. They don't know how to apply them in modern society. Adding some of the most up-to-date research in chemistry into the lecture can help the students know the significance of the chemistry.

Interesting examples related to real life are indispensable. This is one of the best ways to promote the interest of learner. These examples should be based on everyday life and should be used as often as possible. From the examples, the student will find that the difficult concepts become easier to understand.

Using contemporary teaching approaches

There are many theories about teaching and learning. Each of them has its advantages. Using them correctly can greatly improve teaching and learning. The following strategies are some contemporary teaching approaches that can be used in *General Chemistry*.

Concept mapping

Ability to apply knowledge requires a stable conceptual framework. One effective way of establishing a framework is to create 'concept maps'.

Concept maps are diagrams in which various forms or lists of information are classified and their links are shown. Usually, a concept map is divided into nodes and links. Nodes represent various concepts, and links represent the relationships between concepts. Words are used to label the links in order to depict relationships more explicitly.

Much of the content in *General Chemistry* can be designed into concept mapping: atomic structure; molecular structure; coordination compounds; nitrogen fixation and circulation; carbon dioxide circulation are some examples. An example of concept mapping of colligative properties is shown in Figure 1.

A colligative property is one of a set of physical properties of a solvent, which depends on the number, not the identity, of the solute particles in a solution. To explain the concept of colligative properties, we should use the concept of phase. The colligative properties include four items. They are: vapour pressure lowering; boiling point elevation; freezing point depression; and osmotic pressure. Each property can be calculated by a formula. Colligative properties have practical applications in everyday life and in biological systems. Two examples are using salt to melt ice on a footpath (this causes the freezing point of the water to decrease) or an artificial kidney machine. There are many concepts associated with this topic, and many students become confused with the different concepts and formulae. From this concept map, students can build an outline of colligative properties.

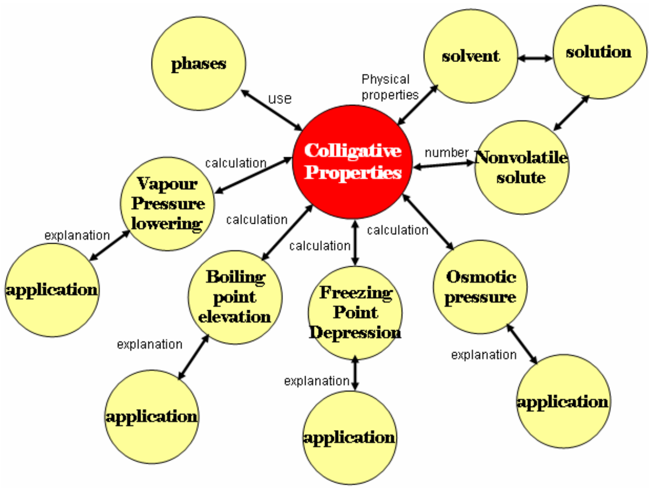

Figure 1. The concept map of colligative properties

In real teaching, the concept map will be introduced step-by-step. After all the content relating to colligative properties is learned, the whole map will be displayed and the links completed.

The concept mapping approach can serve as a key plan for the teacher in determining the best way to teach a topic. It can train students to build up relations among concepts by themselves, and help students to clarify differences between related concepts and motivate them to think more deeply. It also can be used to help students know what it is they have learned and what it is they still do not understand and retain a mind map of the information they are studying.

Problem based learning

Problem based learning (PBL) is a curriculum design and a teaching/learning strategy and is about learning subject knowledge whilst using that knowledge. This approach simultaneously develops higher order thinking, disciplinary knowledge bases and practical skills by placing students in the active role of practitioners (or problem-solvers) confronted with a situation (ill-structured problem) which reflects the real world.

Problem based learning is powerful because it is a learning environment that embodies most of the principles; it encourages active learning and self-directed learning and forces the students to learn the fundamental principles of the subject in the context of needing these principles to solve a problem; it focuses on thinking skills (problem solving, analysis, decision making, critical thinking) and develops lifelong learning skills; and it offers an opportunity to practice and to use many processing skills .

It is important to ensure that the problem satisfies the curricular goals of the course and that the course fits within the curricular framework of the undergraduate program. In PBL classrooms, the choice of problem determines the probability of success of this pedagogy. The premise of PBL is this: if we give students a challenging task that engages them, they will learn to solve problems and they will acquire the associated knowledge in order to solve the particular problem at hand. Their learning will be deeper and more meaningful and will last longer, since it is knowledge that they have constructed themselves within a context and in response to a need.

Once a suitably compelling problem has been chosen, it is important to bring the problem home to the students—to engage and excite them through the use of simulations, videos, newspaper or popular magazine articles, dramatisation, and so on. It is also important that the students identify with the problem. The problem has to offer a clearly defined role for the students to adopt. The problem statement should also specify the deliverables. These project outcomes should be chosen with the class or curricular need in mind and should also appear to be a natural outcome of the problem itself.

There are many real-life problems that need to be solved in the field of chemistry, such as:

- Why do more and more people suffer from skin cancer?
- Why, in summer, do we feel hotter than we did in years past?
- What can be done about diminishing oil reserves?
- How can we purify our water? and
- Why must an iron structure be painted?

All of these problems are suitable for the course of *General Chemistry.*

Case study

A case study is different from problem based learning. It tells a real and complete story, is usually interdisciplinary, has academic and professional significance, and has social implications. As the teaching strategy is interesting, relevant, and motivating for students, it is widely used in teaching.

A good case study should integrate many disciplines and relate to the real world. The case study method involves learning by doing, developing students' analytical and decision making skills, and integrating knowledge skills and learning how to deal with real life problems.

In a case study, students must spend some time studying independently, and learn to work both individually and/or as part of a team. What we should give them is guidance and encouragement, not an absolute direction.

Consequently, the case study method of teaching can improve students' interests in actively learning the knowledge required by the case study and facilitate their deeper understanding of the relevant concepts.

Develop online learning

Online education can be defined as an approach to teaching and learning that utilises Internet technologies to communicate and collaborate in an educational context. This includes technology that supplements traditional classroom training with web-based components and learning environments where the educational process is experienced online.

With the development of the Web, online learning will become more and more important in modern education. Most of The National University of Defence Technology currently engages in some form of online learning. Using the Web as a medium for integrating computer-based learning into an organised course has proved to be an interesting and beneficial exercise. Educational advantages that arise when supplementing a course with web-based tools include:

- enhancing student-to-student and faculty-to-student communication;
- enabling student-centred teaching approaches;
- providing 24/7 accessibility to course materials;
- providing just-in-time methods to assess and evaluate student progress; and
- reducing 'administration' around course management.

The use of the Web is fantastic. It is not only The Resources Room, but also The Virtual Learning Environment. The web provides a learning environment accessible 24 hours a day. It is convenient and interesting for a student to learn new knowledge, seek information, gain feedback on assignments and communicate with teachers and other students via a web site. All students can work at their own pace.

The advantages of online education make a significant impact in higher education today and, as technology evolves, promise to deliver even greater benefits in the future.

This is a work still in progress. The more services offered from the web site, the higher is its value. The web site should offer a wide knowledge of all areas of chemistry to cater for the differing needs and interests of students. We should keep on developing online learning.

Acknowledgements

I would like to express my thanks here to the Chinese Scholarship Council and The University of Sydney for their support. I also want to send my thanks to Associate Professor Anthony Masters, Associate Professor Michael King, Associate Professor Mary Peat and Dr Siegbert Schmid for their successful teaching, their help on a daily basis and their encouragement.

References

Anderson-Inman, L. and Zeitz, L. (1994) Beyond note cards: Synthesizing information with electronic study tools. *The Computing Teacher*, **21**(8), 21-25.

Billett, S. (2002) Workplace pedagogic practices: coparticipation and learning. *British Journal of Educational Studies*, **50**(4), 457-481.

Blackboard Inc. (2000) Educational Benefits of Online Learning. [Online] Available: http://www.blackboard.com/.

Kinchin, I.M. (2001) If concept mapping is so helpful to learning biology, why aren't we all doing it? *International Journal of Science Education*, **23**, 1257-1269.

Kinchin, I.M. (2002) Why professional development should challenge teachers' core beliefs. *School Science Review*, **84**, 77-82.

Lanzing, J.W.A. (1997) *The concept mapping homepage*. [Online] Available: http://users.edte.utwente.nl/lanzing/cm_home.htm.

Ram, P. (1999) Problem-Based Learning in Undergraduate Education. *Journal of Chemical Education*, **76**, 8.

Woods, D.R. (1994) Why PBL? Improving learning and selecting a version of PBL that is suitable for you. In D. Woods (Ed.) *Problem-Based Learning: How to gain the most from PBL*, Ontario.

Woods, D.R. (1996) *Problem-based learning: helping your students gain the most from PBL*. (3rd ed.) Canada: Waterdown.

The application of contemporary teaching strategies in the *Principles of Chemical Engineering* course

Xiong Dan Liu
East China University of Science and Technology (ECUST)
Shanghai
People's Republic of China
200237

Abstract

This article describes how to apply contemporary teaching theories into the *Principles of Chemical Engineering* course in China. The author reviews the present common state of teaching and learning in the curriculum and advocates the adoption of student-centred teaching and learning approaches rather than teacher-centred teaching and learning approaches. Modification of teaching strategies is designed in terms of course objectives, it includes concept mapping, case studies, problem based learning, and so on. Proposals are also made to build up an online learning environment and a combination of multiple teaching strategies to foster generic attributes such as self-learning, critical thinking, lifelong learning and communication skills. New assessment methods are also discussed in the article.

Introduction

With the development of science and technology, the expansion of knowledge is proceeding at an accelerated speed. These are the times of the 'knowledge explosion', only lifelong learners can meet the needs of the development of contemporary society. So higher education must face a challenge—how to develop relevant talents to supply the needs of contemporary society? This situation is especially urgent in China, because the economy is continually developing. Satisfying the needs of economic development requires a diverse range of talents. Higher education in China must keep up with this rapidly developing situation. In response, the number of students is increasing in an unprecedented way. These stimuli raise important concerns for higher education in China—how to improve the teaching quality of teachers and of learning to meet the needs of such large numbers of students?

Course description

Principles of Chemical Engineering is the one core course in the East China University of Science and Technology. It is one important basic technology course in the Department of Chemical Engineering. It is available to third year undergraduate students majoring in chemical engineering, biochemical engineering, environmental engineering, inorganic materials, polymer materials, mechanical engineering, fine chemistry and pharmacy. The prerequisite courses are general chemistry, mathematics, physical chemistry and thermodynamics. The content of the course includes fluid mechanics, particle mechanism, heat transfer and mass transfer.

According to students' particular fields of interest, the course is divided into two streams. One stream attracts 6 credit points with 96 credit hours in an academic year; the other attracts 5 credit points with 80 credit hours in an academic year. Because our students have different backgrounds, these streams should have different characteristics.

Objectives

Principles of Chemical Engineering is concerned with the industrial process in which material in bulk undergoes changes in its physical or chemical nature. The characteristic of the course is its practical emphasis. Students are required to analyse, design, construct, operate and manage these industrial processes according to economic and environmental considerations. So the main objectives of this course are to ask students to: master the basic knowledge and theory of chemical engineering; link theoretical knowledge with practical problems; solve problems in chemical industry processes; and to have the ability to engage in practical work. The students should also have generic attributes such as: critical thinking; communication skills; teamwork; self-management; experimental skills; self-learning; lifelong self-advancement ability; etc. In a word, one of our central goals is to foster chemical engineers of the future.

Current teaching methods in the course
The current teaching methods that we implement in the course *The Principles of Chemical Engineering* are lectures, tutorials, video, final project and experiments. The assessments of students are a mid-term written examination, a final written examination and assignments. The arrangement is as follows.

Table 1. Arrangement of the curriculum

	Method	Credit hours (6 credit points)	Credit hours (5 credit points)
Teaching strategies	Lecture	88	68
	Tutorial	12	12
	Video	3	2
	Experiments	8	6
Assessment	Assignments	After every lecture	
	Projects report	At the end of each semester	
	Examination	At the middle and the end of each semester	

Reflections on current teaching styles

Comparison between traditional and current teaching approaches
As it can be seen from Table 1, the teaching approach most used is lectures supported by problem-solving sessions and laboratory experiments. The lecturer is the principal part of teaching activities. It is a typical teacher-centred teaching method. Under these traditional teaching strategies, students unidirectionally receive knowledge from lecturers, no matter whether they can assimilate it or not. Students are passive knowledge receivers and they seldom take an active part in the teaching activities. The atmosphere in the class is tedious and there is little interaction between lecturer and students in the class. Students depend on the lecturer in learning and lack critical thinking. On the other hand, the learning approach of students is learning by rote. Because the course is based on engineering practices, there are numerous empirical equations, so many students try to remember those equations and parameters that the lecturer spoon-feeds them. Some students treat the problem-solving as solving the equations. When they solve the problem, they try to find known variables, next substitute these known values into equations and parameters, and then get the result. To a great extent, the learning behaviour of students occurs on a superficial level—they remember this knowledge without any understanding.

However, most university lecturers not only use typically teacher-centred teaching approaches, they also use a particularly narrow range of knowledge sources (book learning) and monotonous teaching strategies. Lecturers standing at the platform give lectures to the students, they diligently and persistently impart knowledge to the students but seldom know how much knowledge students have assimilated and whether students can get more than from studying books. Furthermore, traditional assessment methods used in the teacher-centred teaching also encourage students to adopt surface-level learning in order to get good marks in the final examination.

In fact, the function of higher education not only is imparting knowledge but also fostering future talents. So lecturers should take student-centred teaching strategies and engage students in thinking and independent learning rather than encouraging students to memorise the knowledge that lecturers taught them (Entwistle 1998). In the class, students should interact among themselves and with the lecturer. Students should actively participate in the teaching activities in a non-threatening environment (Trigwell 1999). Lecturers should manipulate diversified teaching strategies to help students develop comprehensive range of qualities such as problem-solving skills, critical thinking skills, communication skills, cooperation skills, and independence. The development of science and technology also requires students having interdisciplinary knowledge and a broad perspective on their discipline. In general, 'high score, low capability' students are not valued by 'society'. Therefore we must make some changes in our present teaching strategies.

But the traditional teaching strategies have advantages in the present teaching practices. They have existed for thousands of years in China and exert an important role in teaching activities. Lectures and tutorials still are the main teaching approaches and can not be replaced by other teaching approaches in the short term. Examinations, quizzes, and assignments are effective measures to evaluate students. So traditional teaching strategies still have the momentum to exist for a long time. These cannot be changed all of a sudden. However, contemporary teaching strategies can make up the deficiencies of traditional teaching approaches, perfect the whole teaching system and improve the quality of teaching and learning.

Trends in contemporary teaching strategies
Sweeping changes are occurring in teaching strategies within western universities and many teaching and learning theories are consequently appearing to support these changes. Teaching and learning are closely connected. On the one hand, researchers study students' learning behaviour, that is, how students learn and in what situations students can learn successfully. On the other hand, researchers study the impacts of teaching behaviour on students, that is, how teachers teach and in what situations teachers can make students learn successfully.

The major theoretical development is the move from a behaviourist view of teaching and learning towards the developmentalist and constructivist perspective and view of how people learn science.

The major practical development is the move from strong teacher-centred approaches of teaching and learning towards student-centred approaches and a recognition that students must actively participate in the teaching activities in order to promote deep level learning.

Application of contemporary teaching strategies

As teachers, we have the responsibility for nurturing young minds. Here I describe the use of contemporary teaching strategies to design a detailed curriculum while introducing some changes to the course *Principles of Chemical Engineering*. I think the goal of quality teaching is to make students the biggest beneficiaries of our teaching.

From constructivist theory, quality teaching is most likely to occur when it is student-centred, cooperative in nature rather than competitive, a social act which is shared with peers and validated by the whole learning environment, personally challenging, problem based, task oriented and relevant to the learner. Independent and cooperative group work, PBL, web-based learning, etc., are the hallmarks of effective learning. In the learning process, the lecturer is a facilitator of students' learning. Quality teaching is approached via a wide range of different perspectives, teaching approaches and learning contexts (Brooks and Brooks 1993).

The constructivists see the learner as coming to any learning situation with an existing set of beliefs, values and understandings (correct, partially correct or incorrect) and that the teaching and learning experience they have with the teacher only make sense in terms of what they already know. Effective teaching starts with trying to understand the initial conceptual understanding of the learner. The only person that can change these existing understandings in the mind of the learner is the learner. So if the lecturer can bring into play the subjective initiative of students, the learning outcome will be better. Many teaching strategies such as concept mapping, case studies, PBL, learning by doing, and practical work have this kind of function. The constructivists also pay attention to promoting the personal development and reflection of students themselves, to develop independent learning skills. The more that new teaching strategies can be adapted and integrated into the existing teaching strategies, the better.

Learning characteristics of students

At the present time, most students take shallow approaches rather than deep approaches to learning (Gibbs 1992). They remember only the knowledge that teachers teach them; after the examination, they forget most of what they are taught. They have poor abilities to integrate theory into practical work. Because successful learning only occurs when the learners have motivation and interest, the material must be relevant to the learners. So we should take some measures to improve our teaching outcomes, foster a deep level learning process and make our teaching more student-active and student-centred. We should put more responsibility for learning on the learners. It is beneficial to students if we use modern teaching strategies and teaching skills.

Design of curriculum and application of teaching skills in the course *Principles of Chemical Engineering* course

Concept mapping

Concept mapping is a technique used for representing knowledge graphically and the knowledge graphs represent related concepts that are interconnected. It is often used as part of concept changing teaching. It shows various forms or lists of information that are classified and linked. Using concept mapping can generate ideas (brainstorming), design complex structures and communicate complex ideas. It can aid learning by explicitly and graphically integrating new with existing knowledge. It also can be used as an assessment tool to diagnose misunderstanding and misconception. Using this technique in the course *Principles of Chemical Engineering* can help students understand the interrelationship among different units and concepts. It can help students build up an overall schema of certain topics and promote deep level learning.

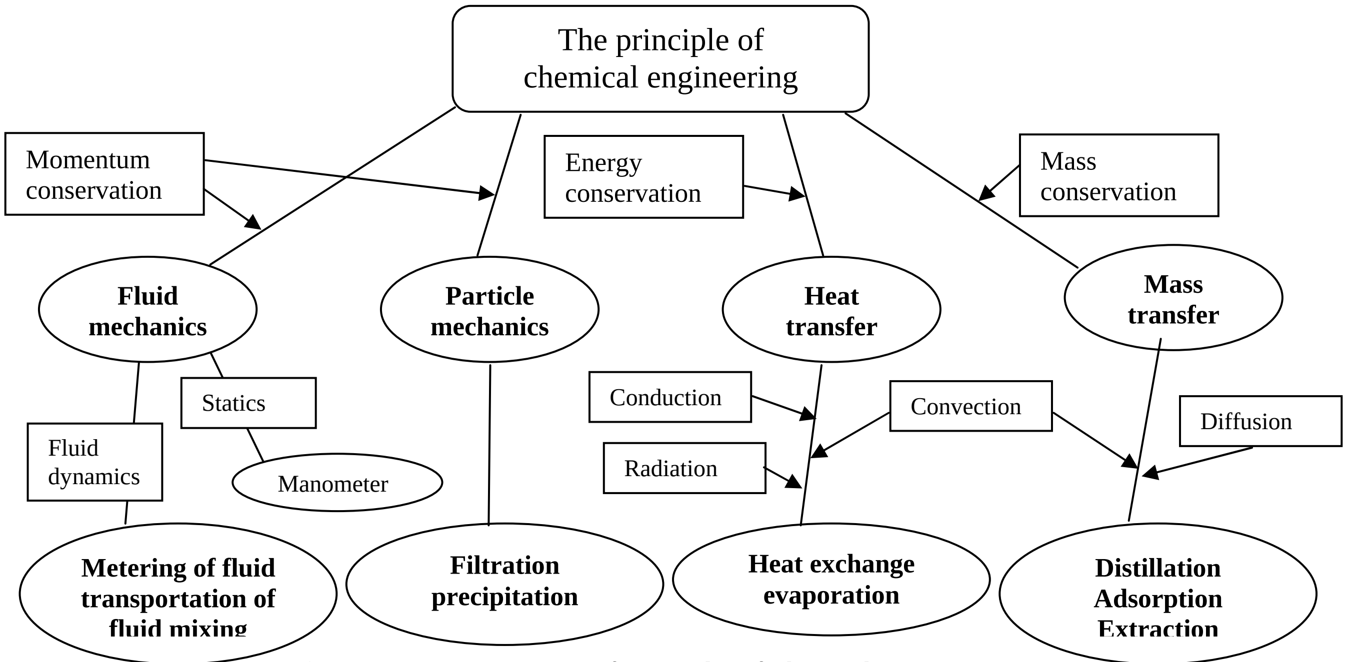

Figure 1. Concept mapping of *Principles of Chemical Engineering*

Case studies

Case studies are specific, highly focused and well defined. Case studies are selected and specified by the lecturer, and ends with asking specific questions which relate to the curriculum. Characteristically, they tend to utilise problems that are always real-world problems. They are inevitably cross-disciplinary to some degree and involve the historical and social background. The solution should be relevant to the students, discipline, or the society in which we live. So I believe the use of case studies is one of the more valuable teaching strategies that should be employed in teaching *Principles of Chemical Engineering.*

For example:

A power generating plant is situated in the suburbs of Shanghai. Because of operator error, a large amount of acid gas is emitted from the absorption tower. When the wind blows toward the southeast, the escaping acid gas coincides with a rain shower. The accident caused considerable damage to the local farmers' crops.

The questions asked are stated below.

- What kind of chemical absorption has happened in the tower?
- How does the acid rain form?
- What is the emission standard of waste gas from the power plant?
- According to the emission standard, what should be the height (metres) of the absorption column?
- What other methods can be used to reduce the waste gas of the power plant?
- What are other outcomes of the accident?
- What are the effects of acid rain on the environment?

This series of questions makes students interested, motivated and has relevance to their future profession. The questions engage the learners and require them to be active in developing ideas further. Students can learn more from the case studies than from book learning.

The PBL approach

Constructivism advocates problem based learning (PBL)–a curriculum design and a teaching and learning strategy which simultaneously develops higher order thinking, disciplinary knowledge bases and practical skills by placing students in the active role of practitioners (or problem-solvers) confronted with a situation (ill-structured problem) which reflects the real world (Ram 1999). The characteristics of PBL are using context-based, real-life situations, focusing on thinking skills (problem solving, analysis, decision making, critical thinking), requiring integration of interdisciplinary knowledge, promoting self-directed learning and developing lifelong learning skills, involving sharing and interacting with others in small groups.

In chemical engineering, there is large number of applications of fundamental scientific knowledge into the real world. The old discipline of chemical engineering is intimately integrated with other disciplines to create innovative technology. So PBL conforms to the trend of interdisciplinary crossing of contemporary technology. For example, we might take the artificial heart as a specific instance.

Table 1. Sample problem

Problem	Design and analyse an artificial heart
Arrangement: The whole project lasts 6 weeks. 3 to 5 students form a group. At the start of the project, the lecturer gives a mini-lecture concerning the topic and the criteria of assessments which include peer-assessment and self-assessment. Students submit preliminary reports at the fourth week, the lecturer will give some suggestion for their assignment and organise a tutorial with students to discuss issues arising from the reports. At the end of the sixth week, the students must give a group oral presentation to the class and hand in a final written report and assessments. This concludes the PBL process.	
Knowledge background	Fluid mechanics, biomedical, bioprocessing, biomaterial
What students should do	Analyse and discuss the problem in a small group Investigate and collect information, data Understand what engineering principles and biomedical knowledge are used in the design Calculate the answers to fluid mechanics Put forward advice how to improving the devices Evaluate the existing artificial hearts Present an oral and written report Communicate among group peers
What the teacher should do	Provide some information (how to use the library and the internet to seek literature and other information) Facilitate self-study Supervise the process of learning Assess the effect of self-learning
Further problems derived from the activity	To what other fields can this knowledge of chemical engineering be applied?

In PBL, problems are general ill-defined real-world problems and the students are required to be active in identifying aspects of the problem and its solution pathways. Building up a PBL environment is essential to enable students to develop generic skills. Applying appropriate chemical engineering principles to solve open-ended problems can make students understand that engineering is practiced in non-ideal, poorly defined situations. There is no one right answer. A good engineer is able to successfully solve these practical problems.

Suitable use of online learning and teaching approach

With the development of information technology, the Internet has become one of the new learning and teaching resources. The online learning environment can facilitate independent learning and independent thinking, develop the abilities of information retrieval, lifelong learning and using new technology. It addresses a deficiency of traditional teaching and learning methods. It can provide timely feedback to students, especially when an individual lecturer cannot meet the needs of increasing numbers of students. The lecturer and students can exchange information through email or chat rooms. Students can visit a course web site to get instruction from the lecturer and other students. Students can get feedback concerning their assignments, tutorials, and projects. Suitable use of this resource can improve the efficiency of teaching and learning.

Combination of multiple teaching strategies

In the teaching practices, the lecturer should use multiple teaching approaches and skills in the class. As the ancient great educator and thinker Confucian said, according to the different makeup of students, different teaching strategies should be taken. That is, different students should be taught by different methods. A single method is not suitable for all students. Because different students adopt different methods to study, they have different sensitivities to different teaching methods. So different teaching strategies can achieve different goals. On the other hand, if we adopt diversified teaching strategies, it not only can promote deep level learning but can also make students acquire training in different aspects. It will help to foster the generic attributes of students such as self-learning, critical thinking, lifelong learning and so on.

Assessment of student performance

The means of assessment should be diverse and be helpful to the personal development of students. Contemporary teaching theories maintain that formative assessment should be ongoing and designed to inform learners on what they do and do not understand. It should occur during learning and not at the end of it, it is a skill that students can take away with them. Traditional assessments examine how much knowledge students can recall and are not structured from the point of view of the personal development of the student. So any attempt to evaluate the learning outcomes of students must not just include knowledge and skills, but also include personal development. In addition to conventional assessment methods, including assignments, examinations and project reports, we should use new strategies to modify the assessment system so the assessments can influence the learning behavior of students and promote deep level learning. New strategies should include assessment of presentations, PBL, case studies, group project work, etc. Furthermore, assessment should involve students in the assessment process, integrate assessment into the learning process, and provide constructive suggestions to students. The lecturer can set the criteria of assessment and involve students in self-assessment and peer-assessment while the students do some cooperative group work. In summary, we should use more formative, rather than summative, assessment to estimate the performance of students.

Conclusion

In conclusion, higher education should not only deliver specific knowledge and skills but also attitudes and aptitudes. Although contemporary teaching and learning theories and pedagogies are widely practiced and tried in different disciplines in the western world, taking into account the situation and curriculum characteristics, I plan to keep some strong aspects of current teaching strategies that I have used and will try to integrate some of the new teaching approaches to improve students' learning behavior in my later teaching activity. I will use the Internet and information technology to improve teaching and learning. Assessment methods should be diversified and focus on fostering the spirit of creativity and lifelong learning skills. Students will benefit from new teaching strategies thus improving their employment prospects and career opportunities. Meeting these objectives will require a great deal of energy, but I think it will be beneficial.

Acknowledgements

The *Teaching Science in English* program is supported by the China Scholarship Council (CSC). The author would like to acknowledge the CSC for giving him this opportunity to take part in the program.

The author would like to express sincere thanks to The University of Sydney. Special thanks to Associate Professor Mike King from the Faculty of Education, and Associate Professor Mary Peat from the Faculty of Science for their successful teaching which introduced the author to contemporary teaching and learning theories and strategies. The author greatly appreciates Associate Professor Tony Master for his guidance and suggestions with writing this paper, Dr Siegbert Schmid for his help and providing on-going assistance, and other staff working on this program.

References

Brooks, J. and Brooks, M. (1993) *The case for a constructivist classroom.* Alexandria, VA:. ASCD.

Entwistle, N. (1998) Improving teaching through research on student learning. In J. Forest (Ed) *University Teaching International Perspectives*, Garland Publishing Inc, NewYork.

Gibbs, G. (1992) *Improving the quality of student learning: based on the Improving Student Learning Project.* Bristol: Technical and Education Services.

Ram, P. (1999) Problem-based learning in undergraduate education. *Journal of Chemical Education*, **76**, 1122-1126.

Trigwell, K., Prosser, M. and Waterhouse, F. (1999) Relations between teachers' and students' approaches to learning. *Higher Education*, **37**, 57-70.

Zeegers, P. (2001) Approaches to learning in science: a longitudinal study. *The British Journal of Educational Psychology*, **71**(1), 115-129.