

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

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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.

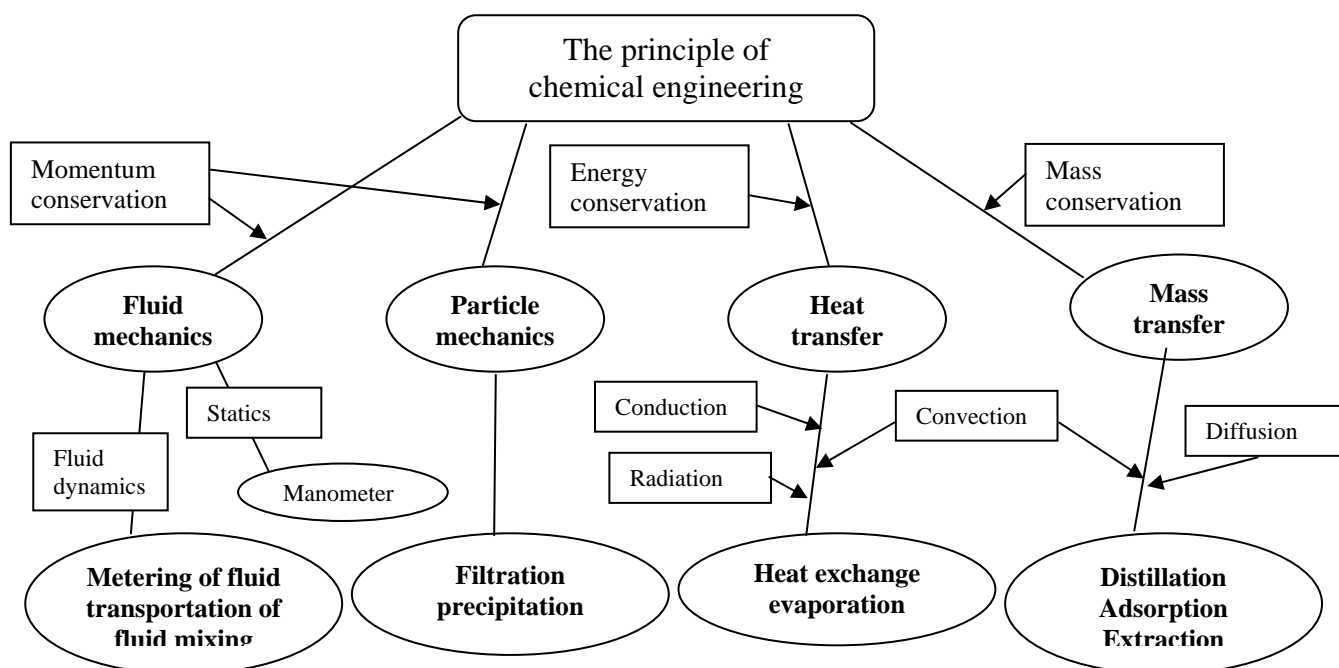


Figure 1. Concept mapping of *Principles of Chemical Engineering*

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.

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