

Using contemporary teaching and learning strategies in *Organic Chemistry* teaching

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Abstract

This paper describes how to introduce some contemporary teaching and learning strategies in organic chemistry teaching in order to make teaching and learning more efficient and practical. The strategies including case studies, problem based learning, concept mapping and online learning are discussed in detail. All these approaches can help students learn actively as well as improve their lifelong learning skills. We hope these methods can change teacher-centred teaching into student-centred teaching and learning actively.

Introduction

In our modern, high technology society, everything moves at a fast pace, so it is necessary for higher education to make changes to provide more useful members of society. The pace of technological change and the improved access to new technologies means that individuals will constantly need to reinvent themselves. Universities need to deliver not just specific skills and specific knowledge but also the attitudes, aptitudes and problem-solving skills, which will sustain learning throughout life. This means that encouraging deep level processing of information leading to lifelong learning is necessary. The teacher's responsibility does not focus on the content they teach, but on directing students to develop these lifelong learning skills. It is important to let students know that the responsibility for learning is with the learners themselves. Sometimes teachers focus on the knowledge they teach, but don't pay enough attention to developing students' generic skills. They concentrate more on how teachers teach, and less on how students learn. So some kind of teaching reformation is necessary. At the University of Sydney, we were introduced to many theories of teaching and learning in science. For example, constructivist learning theory and pedagogies, problem based learning and pedagogies, case studies, concept mapping, student-centred and collaborative learning practices (Dressel and Marcus 1982; Woods 1995), and the use of online teaching and learning technologies and strategies in science. Several of them can be used in our practical teaching.

Course description

In the College of Chemistry at Northeast Normal University of China, I teach organic chemistry. The term organic suggests that this branch of chemistry has something to do with organisms, or living things. Organic chemistry is the chemistry of organic compounds. It includes not only compounds from nature but also synthetic compounds – compounds invented by organic chemists and prepared in their laboratories. Organic compounds are everywhere around us, in our foods, flavouring, and fragrances; in our medicines, toiletries, and cosmetics; in our plastics, films, fibres, and resins; in our paints and varnishes; in our glues and adhesives; and, of course, in our bodies and those of all other living things. From the point of view of understanding nature, organic chemistry is a very important subject.

In our university, *Organic Chemistry* is one of the most important courses for second year undergraduate students majoring in chemistry. In our organic teaching, the most commonly used teaching methods include lectures, tutorials, duty tutors and laboratory classes. Most of them involve teacher centered teaching. Students receive knowledge passively. These traditional methods do not stimulate their interest in this subject. Most of time, the knowledge they get is only superficial, they are unable to reach a deep level of understanding.

Modification assumptions

Using a case study

A case study is an educational story with a message and a question. The case is a real and complete story, is usually interdisciplinary, has academic and professional significance, and always has a social implication(s). It can be a critical incident, slice of life account, appraisal/consultant report, personal story/narrative, newspaper story, case history, scenario, video case/trigger film and simulation activity.

What makes a good case?

- The incident has emotional power.
- The incident entails difficult choices.
- It is open-ended, allowing multiple interpretations and solutions.
- It entails fundamental/underlying value conflicts.
- It speaks to important aspects of the goals for student learning.
- It addresses issues that require or benefit from collegial discussions.
- It is related to the important curricular and pedagogical aims of the program.
- The situation is memorable and repeatable.

How should teachers choose a suitable case in their own discipline?

- Identify clear learning objectives.
- Know your learners.

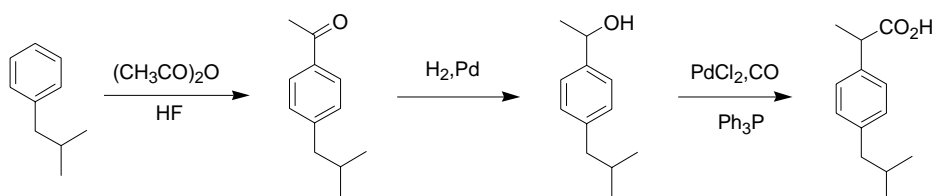


Figure 1. The synthesis route for *Ibuprofen*

Ibuprofen is a very important anti-inflammatory drug. It is the active ingredient of many over-the-counter drugs used to relieve the pain of headaches and arthritis. Approximated 11000 tonnes of this simple carboxylic acid were synthesized in 2000! A large number of *ibuprofen* syntheses have been developed and several of these have been commercialised. The synthesis shown in Figure 1 begins with the reaction of isobutylbenzene with acetic anhydride using hydrofluoric acid (HF) as the solvent. This is a variation for the Friedel-Crafts acylation in which the anhydride serves as the source of an acylium ion. Through clever engineering processes, the reaction solvent (HF) serves as both the acid catalyst and solvent (recyclable) for the reaction, and water is the only major reaction by-product. The second step is an addition reaction, catalytic hydrogenation of acetone to an alcohol. The final step is a reaction we will not have discussed that involves palladium-catalysed insertion of carbon monoxide into a benzylic C-O bond to give the carboxylic acid (*ibuprofen*). This reaction is clearly atom economical. Finally, the chemical yields of all the reactions are very high and very little chemical waste is produced.

- Understand how the concepts of the case fit into the overall concept map for the course or unit..
- Actively involve learners.
- Model professional thinking and action.
- Provide direction and feedback.
- Create a collaborative learning environment.

I will give a real example in my teaching in the course – how to synthesise an organic compound, during which a case study is fully applied. Synthesis is the most important part of organic chemistry. In previous lectures, after presenting students with all the basic organic reactions, we give them target molecules, we ask them to use these reactions to design and synthesise target molecules. Since all reactions are in the textbook, sometimes students feel bored; during the whole molecular design and synthesis process nothing is done by them. Through the introduction of a case study, I want to change this situation. As an example of a case study, green chemistry and synthesis can be selected. From our increasing need to respect nature and protect our environment has come a new field of chemistry – green chemistry – the design and development of chemistry that is environmentally friendly and avoids pollution. This presents many challenges to organic synthesis. One notion is that an ideal synthesis provides a useful compound in a single step, with the formation of no disposable by-products by a process that consumes little energy. Such a synthesis would certainly be environmentally friendly! This goal is seldom met, but general principles can be applied to try to approach this ideal. The synthesis of *Ibuprofen* can be used to illustrate these green chemistry concepts to students (Figure 1).

After students know that organic synthesis plays an important role in the real world and can improve our lives, they may be interested in this subject. They will be intrigued by the questions following the case. The teacher will direct and assist students to answer these questions.

- What kinds of ideal reactions have been learned – classify these reactions (addition reactions and isomerisation reactions do not create any by-product, and so can be said to be atom economical – all of the atoms in the reactants appear in the product, on the other hand, elimination reactions and substitutions necessarily produce by-products – attention will have to be devoted to disposing of or developing uses for by-products)?
- What kinds of other general strategies can be applied – use of catalysts, minimising the use of heavy metals, use of molecular oxygen and hydrogen peroxide as oxidants, minimising the use of solvents in reactions?
- Thinking about how to design and synthesise target molecules from the green chemistry point of view?

Provide groups of students with similar tasks of synthesizing different target molecules. Each student would be asked to give a written report and each group to give a presentation in 1-2 weeks.

Using problem based learning (PBL)

Problem based learning is a curriculum development and delivery system that recognises the need to develop problem-solving skills as well as the necessity of helping students to acquire necessary knowledge and skills. Indeed, the first application of PBL was in medical schools which rigorously test the knowledge base of graduates. Now many universities world wide use this strategy to teach their students (Vernon and Blake 1993). PBL utilizes real-world problems, not hypothetical case studies with neat, convergent outcomes. It is via the process of struggling with actual problems that students learn both content and critical thinking skills. In problem based learning, the problem may not be solvable, but nevertheless provides a rich environment for learning. The aim is to learn rather than to solve the problem. Problem-based learning almost always employs groups of students working co-operatively, sharing ideas, dividing up the learning to be done, briefing each other and solving problems co-operatively. Students with such ingrained skills are well prepared for occupations which rarely have a supervisor who has time, inclination or knowledge to tell the worker what to do. They are also well

prepared for the explosion of knowledge which gluts the world today. Here are some real-life problems that are suitable examples for the *Organic Chemistry* course.

- Why is vitamin A so important for eyes?
- How can some kinds of organic compounds produce fluorescence?
- How can air pollution from automobiles be reduced?
- How can glucose in blood be detected?
- How can a breath-alcohol screening test be conducted?
- How can we find a good substitute for tobacco to help smokers get rid of smoking?

A PBL example

How can a potent, but less addictive painkiller be found?

- What are the commonly used and most effective painkillers? (Morphine comes from the unripe seedpods of the opium poppy, (Figure 2)).
- What are the structures of these compounds? (Figure 2)
- What kinds of side effects do they induce? (It is addictive and depresses the respiratory control centre of the central nervous system)
- How can the most effective painkiller be chosen as a model for drug design? (For example, Meperidine)
- How can the designed molecules be synthesised?
- Construct a new hypothesis.



Figure 2. The chemical structure of two commonly used painkillers (Morphine and Merperidine) and a photograph of the unripe seedpod of the opium poppy

In fact, the procedure a teacher might give is not the only way to solve this problem. Through this learning process students can propose their own innovative methods. Because the problem is a real world question, we do not hope the student can solve it. In fact, it is difficult for trained scientists to solve it. The problem only provides a rich environment for learning. The kinds of conclusions the students draw are not the main point, the purpose is for students to learn problem solving skills. This problem solving process encourages a deep understanding of the nature of problem. Discovering a new method to solve the problem develops their independent learning, a skill they can retain life long.

Our staff will also face many difficulties applying the PBL methods. We are in a knowledge explosion society, the real world problems change frequently. Teachers also need to renew their knowledge and need more time to find new problems and their solutions. They cannot use the same problem for several years like the content of many lectures used now. Since all staff in China must conduct research as well as teach, the limitations of time and energy make this

kind of reformation a little difficult. We still have a long way to go.

Using concept maps

Certain abstract basic concepts for each discipline are difficult for students to understand. One method to solve this problem is to use a concept map teaching strategy. Concept mapping is a technique used for representing knowledge graphically, it is derived from the constructivist theory. Knowledge graphs are networks of related concepts that are interconnected. Usually, the graphs consist of nodes and links. Nodes represent related concepts within a topic; links represent the relationship between concepts (Lanzing 1997). Concept maps can be used at the start of a topic, which can help students establish the main relationships between different concepts. Then the teacher can focus on one or two important aspects, and let students study other concepts by self-directed learning. For example, when I teach stereochemistry, students will face a lot of new concepts. Faced with a fully organized concept map (Figure 3), students can understand the relationships of these concepts clearly.

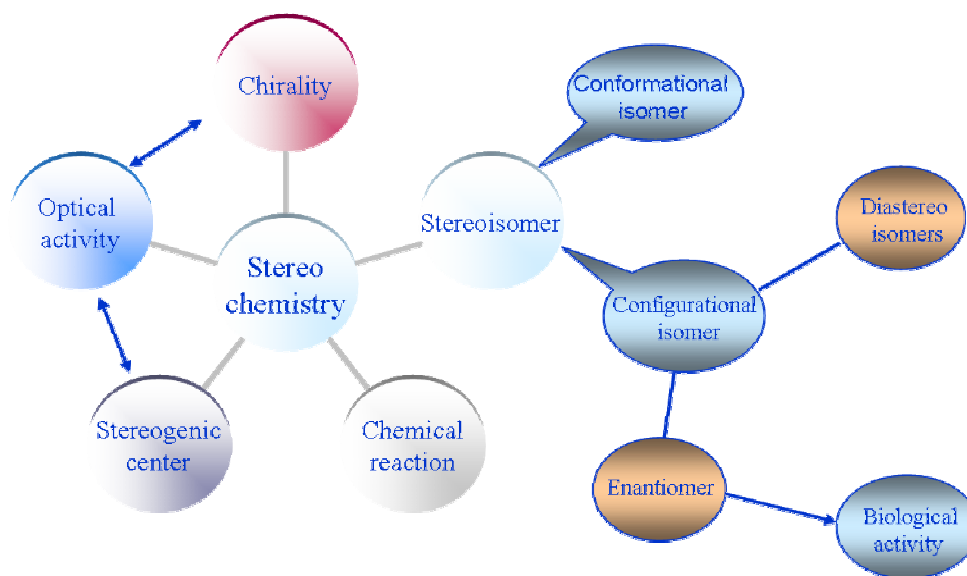


Figure 3. Concept map of stereochemistry

Online teaching and learning

The Internet develops with striking speed in today's society. We can find most things we want to learn on net, so online teaching and learning is necessary for both teacher and student. A customized set of web-based tools to support the learning environment has been designed and built. The various tools and their functional elements have been described in several recent papers. (Oliver and Omari 1999; Oliver, Omari and McLoughlin 1999). The style of online learning at the University of Sydney includes *WebCT*, *ChemCAL* and self-help problems. Some of the benefits of online learning are:

- to support lectures: lecture notes online;
- to support independent learning: increased access to information;
- to help staff improve teaching; and
- interactivity and communication: instant feedback.

In our university, a series of online learning systems has not been established. In the college of chemistry, such initiatives are hindered by the lack of funds, staff and continued support and development. A comparatively longer time is needed to develop on-line learning systematically. But there are also many things we can do now:

- use existing resources online;
- integrate some other teaching and learning strategies with online learning;
- introduce advanced *WebCT* and *ChemCAL* systems;
- let students' learning improve the teacher's teaching; and
- apply funds actively to develop online learning.

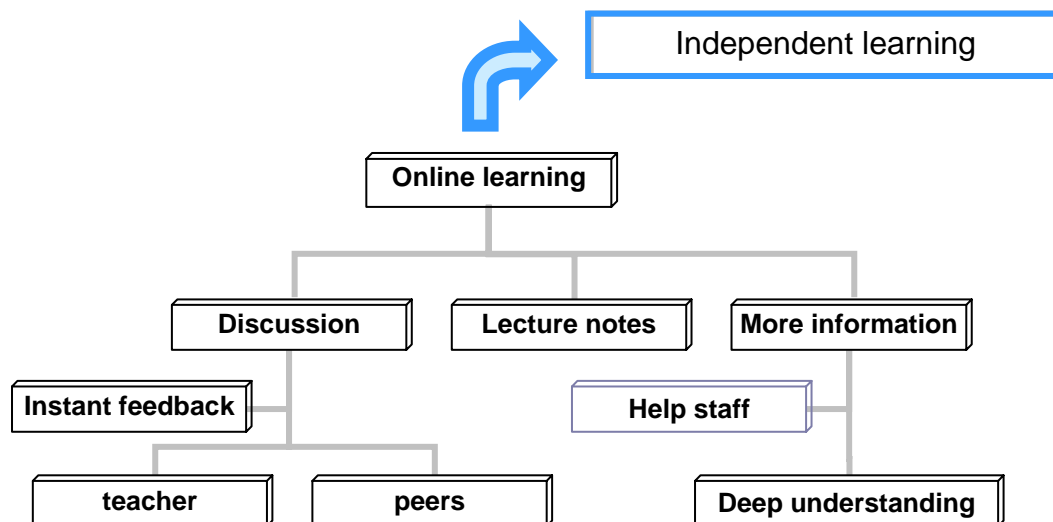


Figure 4. Teaching procedures using the web

For example, when we use the existing online resources, a teaching procedure can be described as in Figure 4. We put our lectures online, give some references to web sites or books for students to read, conduct discussions with students online, and encourage them to discuss problems with peers. Discussion results give us instant feedback to improve our teaching methods or course content. We can also make full use of web resources. Encouraging students to read more information corresponding to the lecture may assist them to deeply understand the content of lectures. Allowing them to find more practical cases and real world problems for their self-directed presentation will lead to their independent learning, it is also a good way for the teachers to discover the students' interests and enrich the lectures.

Assessment

The whole teaching and learning process needs to be assessed. Some research suggests that students will use different forms of understanding depending on the type of assessment requirement (Biggs 1992; Ramsden 1992). The traditional assessment is usually based on assignments and a final examination. In fact, it is a shallow approach: students employ rote learning and simply repeat ideas that have been given to them. This superficial, memorizing study regime often enables students to get high marks. But after students pass the examination, most material is forgotten. Few of the skills that are required to be a successful autonomous learner are gained during this process. In this context, then, how can students be assessed effectively? The answer is to adopt a deep approach, integrating assessment into the learning process. Assessments should depend on the depth of understanding of the subject, which is shown in the self-directed presentation or group project work. Students who are required to prepare an essay/report will direct their attention to the general principles of the subject and hence adopt a deep approach to learning. During this procedure, the teacher can provide feedback to enable students to improve their understanding, diagnose misunderstandings and assist them to learn more effectively. This kind of assessment also enables students to remedy any learning deficiencies prior to the final examination. The traditional assessment provides no chance to consolidate knowledge during the learning period, nor does it provide timely feedback to students. Some other formats, such as self- and peer-evaluation, can also be added into assessment system. In fact a deep approach to assessment is associated with some contemporary teaching and learning strategies, such as case studies, PBL and online learning, which incorporate oral or written reports. Although it is sometimes difficult to find a suitable way to evaluate the student during the active learning process, we can change the assessment system gradually. It is better to use both formative assessment and summative assessment.

Conclusions

Through adding a case study, PBL, online learning and some changes in the assessment system, we hope to see some progress in teaching outcomes. It is very important that all staff in the university understand the crucial effect of teaching reformation. It is a long term and complex task. We don't expect striking variations now, but we believe they should become evident in the near future.

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