Using appropriate strategies to improve teaching and learning in organic chemistry and organic chemical experiment courses

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Abstract

In China, higher education needs to be reformed profoundly. This kind of reform must focus on making learning more efficient and improving educational practice. This is a challenge for us. Like other courses, the practice of teaching organic chemistry requires change in order to improve teaching and learning. This may require a rethink of our approach to education. In this article, the author discusses some of the new teaching and learning strategies encountered at the University of Sydney and describes some appropriate changes in teaching style that will be introduced to improve student learning in the organic chemistry and organic chemical experiment courses offered by the College of Chemistry at Jilin University of China. The author address a variety of issues in the curriculum, including problem-based learning (PBL), case study, concept mapping, and multi-step organic synthesis. All of these teaching and learning approaches can help students' learning and improve their personal skills as well. These methods are intended to stimulate the students' interest in learning organic chemistry and in the organic chemical experiment courses.

Introduction

In the college of chemistry, Jilin University of China, *Organic Chemistry* is one of the most important courses for third year undergraduate students majoring in chemistry; chemical engineering; applied chemistry; biochemistry; medicine; environmental science and materials science. It is also a very important subject for all students of chemistry. At the same time, the pre-professional student will also benefit greatly from this course.

What is organic chemistry?

Organic chemistry is a subject that studies organic compounds. Organic compounds are hydrocarbons and their derivatives. There are many kinds of organic compounds in the real world. Everyday we eat organic compounds such as seafood and beef that contain protein, bread and wheat biscuits that contain amylose or farina. We drink organic compounds such as coffee and tea that contain caffeine, or orange juice which contains fructose and fruit acid. We use organic compounds such as clothing that is made of cotton, wool, linen, or chemical fibres. Almost all fuels are organic compounds except carbon, carbon oxide and hydrogen. Most medicines are organic compounds. Similarly most dyes are organic compounds. So organic chemistry is a very important subject for all students of chemistry to study.

Course teaching system

The main objectives of this course are to: provide a basic understanding of some organic principles; introduce students to the characteristics of several kinds of organic compounds; enable students to learn how to design and synthesis some important organic compounds; and help students learn to use some basic theory to solve real world organic problems.

In our college, this course usually involves 100 hours of lectures and 168 hours of laboratory work. It needs two semesters. In the first semester, students will learn: the naming; properties; reactions; and reaction mechanisms for the simpler organic functional group families. In this semester, I will explore the naming and reactivity of the simple organic functional groups. Students will study the following organic compounds and organic theory in great detail: alkanes; alkenes; alkynes; alkyl halides; aromatic hydrocarbons; stereochemistry; alcohols; phenols; and ethers. In the second semester, we will explore the naming and reactivity of the more complicated (but more interesting) organic functional groups and the chemistry of the carbonyl group will be explored in great detail. The function and reactivity of biologically important molecules such as carbohydrates, amino acids and proteins will also be explored.

How organic chemistry is taught at present

In our college, this course is usually taught by a didactic approach: the teacher delivers formal lectures to transmit knowledge and students receive it passively, so sometimes students find it boring. We also use some new methods, such as multimedia technologies, 3D plug-ins and *Flash*, in order to develop interest in this course, but the effect is not very marked. I think that we must make some modifications in this course using some appropriate teaching and learning strategies in order to help my students take a deep approach to their learning.

Teaching and learning strategies learned at the University of Sydney

At the University of Sydney, we have learned several theories of teaching and learning in science such as constructivist theory; problem-based learning; contextual learning approaches in science; student-centred and collaborative learning practices in science (Dressel and Marcus 1982; Woods 1995); the use of online learning; case studies and concept mapping. Some of these strategies will be very useful in my lectures. I will do some modifications in my teaching, and use some appropriate strategies to improve teaching and learning in organic chemistry and organic chemical experiment courses.

Modification assumptions

Based on what I have learned at the University of Sydney, I will undertake some modifications to my teaching. The main procedures are outlined below.

Modifications in lecturing

In my lectures on the organic chemistry, I will try to modify and implement the following teaching strategies:

- **Using problem-based learning (PBL)**

Problem-based learning (PBL) is a curriculum design and a teaching/learning strategy. Many universities use this strategy to teach students (Vernon and Blake 1993). PBL is also a learning environment that embodies most of the principles that we know to improve learning – being active, cooperative, providing prompt feedback, and tailoring learning to students' preferences with student empowerment and accountability as a central idea. (Nendaz and Tekian 1999). The aims of PBL are to help students develop higher order thinking, to provide disciplinary knowledge bases and skills by placing students in the active role of practitioners (or problem solvers) confronted with a situation (ill-structured problem) that reflects the real world (Savin-Baden 2000). Rather than focusing on facts, PBL: encourages active learning and self-directed learning; is context-based using 'real life' situations; focuses on thinking skills (problem solving, analysis, decision making, critical thinking); requires integration of interdisciplinary knowledge, skills or behaviour; and develops lifelong learning skills. Students who acquire scientific knowledge in the context in which it will be used are more likely to retain what they have learned, and apply that knowledge appropriately (Albanese and Mitchell 1993; Bond and Felletti 1991). I think that PBL will be a very useful strategy in teaching organic chemistry. I will use this strategy in my teaching and try to modify the problem-based learning approaches used in the course on organic chemistry when I get back China. The main aim of this trial is to have students learn the theory of organic chemistry by lectures combined with problem solving projects rather than by just getting information from my lectures. It will be very helpful to make students become more independent, lifelong and active learners. The example that I will attempt to use in my PBL teaching is:

Why do some clothes lose colour easily?
(Sub-question: What is a good dye?)

In this PBL exercise, students must use self-directed learning to discover the following knowledge of organic chemistry:

- aromatic compound;
- conjugate compound;
- organic synthesis; and
- dyestuff chemistry.

Structured learning events include:

- the sorts of dye;
- the characteristic of a good dye;
- the design of a dye; and
- the synthesis of a dye.

When students have learned all of the above knowledge of organic chemistry, they can answer the title question, and I will ask them to hand in a written report in 4-6 weeks.

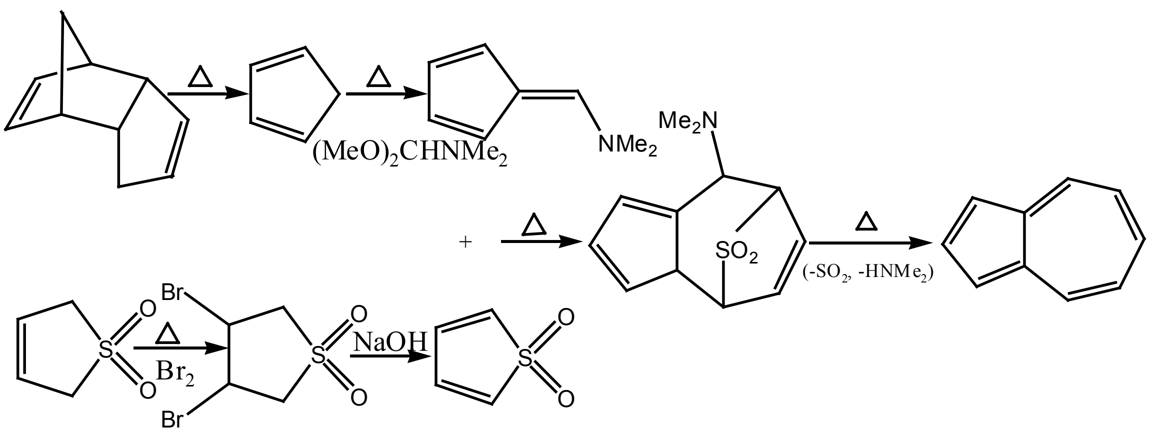

Figure 1. This example can give some enlightenment

At the beginning, I will give a good example that comes from the School of Chemistry at the University of Sydney, to my students, about the synthesis of azulene. Azulene is a beautiful and interesting compound with many unusual properties. It can be used as a very good dye, because it has a very beautiful blue colour, has very good dye fastness and it is very stable. Azulene is extremely expensive (1999: \$193/g) and its synthesis is generally considered to be beyond the scope of the undergraduate organic laboratory (McLeod and Hambley 2003).

- **Using a case study**

The case study is a teaching/learning strategy. It is a story with a message and a question. Case studies educate through stories and the story must be interesting, relevant, motivating and related to the real world of the student

I will tell a real story to my students as a case study.
In 1998, Shanxi province, China, a person made some bad wine using industrial alcohol, and many people drank it, over 200 people were poisoned, and 36 people died.
I will ask my students the question: 'why do people die after drinking this kind of bad wine?'.

Students must answer the following small questions if they want to answer the big question:

- what is alcohol?
- what does wine contain?
- what is a good wine?
- how to produce wine? and
- how to make wine safe to drink?

And students can use web sites, teamwork, discussion and other approaches to learn the following aspects of alcohol chemistry:

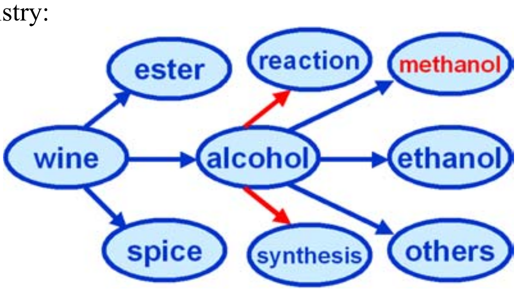

Figure 2. Alcohol Chemistry

- **Using concept maps**

Concept maps are diagrams in which various forms or lists of information are classified and their links are shown. It is derived from the constructivist theory. Usually, a concept map is divided into nodes and links. Nodes represent various concepts, and links represent the relationships between concepts (Lanzing 1997). Words are used to label the links in order to depict relationships more explicitly (Anderson-Inman and Zeitz 1994). The concept map can serve as a key plan for the teacher in determining the best way to teach a topic. It can also be used to help the teacher to explain why we are focusing on a particular aspect of a topic so that the students can see how particular pieces of information fit into the overall schema. Concept maps 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. Much knowledge in organic chemistry can be organised by concept mapping.

For example, there are many concepts that are very difficult to understand and to memorize in stereochemistry, but we can use the following concept map to help students understand and learn these concepts easily.

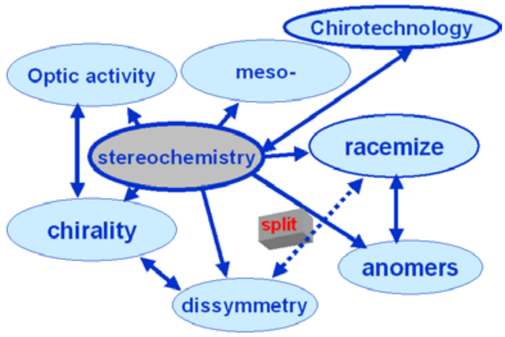

Figure 3. Concept map for stereochemistry

As another example, we can use the following diagram when we study the reactions of alcohol. It can also help students easily learn many reactions of alcohols.

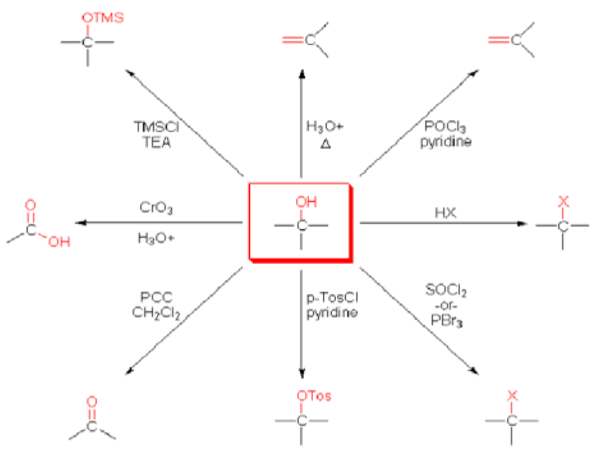

Figure 4. Reactions of alcohol

Modifications in experiments

While chemistry has unquestionably improved our lives, these advances have also generated environment problems, in particular, substantial amounts of pollution are the result of the development of chemical industries. So, the concept of green chemistry, or environmentally friendly chemical industry, has been developed in the last decade. This concept focused on the decrease in pollution and an increase in the efficiency of using chemicals. For this purpose, the usage of chemicals should be regarded as a union, or a system in the process of experiments, called 'atom economy'. We believe that this unifying thought advocated by green chemistry, is not only relevant to specific experimental operations, but also to the design of the whole teaching system. Thus, we propose here that the traditional experimental teaching system should be reformed accordingly to: either emphasise the connection between all the fundamental experimental branches of chemistry; or the arrangement of organic chemical experiments. Accordingly, presented here are some suggestions related to the successive arrangement in the teaching of basic organic chemical experiments.

- **The successive arrangement in basic chemical experiments**

The original teaching system of chemistry in our college arranged several branches of basic experiments, containing inorganic, analytical, organic and physical chemical experiments in the period prior to graduation. This experimental system resulted in the separation of chemical experimental knowledge into blocks. Now, the target of advanced education is not only the transfer of knowledge, but how to increase the students' ability to resolve a problem which is more important than the transfer of knowledge itself. In this case, the traditional experimental teaching system should be reformed in order to educate the talented students. Therefore, we suggest that these four branches of basic experiments be connected with each other. For example, kinetic experiments in physical chemistry should be connected with analytical chemistry. The students should be asked to look up references to design an experimental process before conducting an experiment. On the other hand, the sample detected in an analytical experiment can be compared with those synthesised by the student. In this novel experimental teaching system, the union of the chemical experiment in college is emphasised by the connection of these separated branches.

- **The successive arrangement in basic organic chemical experiments**

The basic organic chemical experiment was divided into two parts to be carried out in two semesters. The first semester is devoted to training in basic chemical operations involving:

Figure 5. Basic chemical operations

Many kinds of organic compounds can be synthesised in the second semester for reinforcing the basic synthetic techniques. This traditional teaching system cannot attract the students' interest, since no relationship exists between the experiments. Moreover, the chemical reagents used in each experiment cannot be reused in a following experiment.

Although we insist on the traditional pattern in our arrangement of basic organic chemical experiments, in which training in basic operations and the practice of synthesis are also allocated in two semesters, the order of experiments in the first semester are arranged as follows:

1. recrystallization of benzoic acid in ethanol and water;
2. distillation of the consequent aqueous ethanol solution;
3. extraction of caffeine by using the previously distilled ethanol;
4. fractional distillation to reclaim the ethanol;
5. and the recovered ethanol can be used as a reactant in the esterification of benzoic acid.

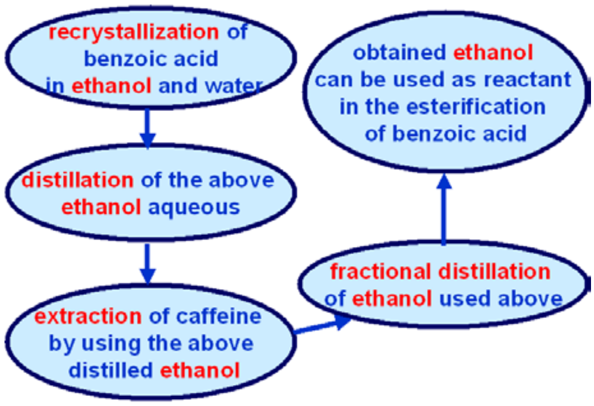

Figure 6. Sequence of experiments in first semester

In this way, the efficiency of ethanol usage is markedly increased, leading to experimental cost savings and pollution reduction.

Second semester is devoted to the practice of synthesis. Two sections each involving multi-step synthesis are arranged as shown in Figure 7.

Although there are not many reaction types contained in these two sequential syntheses, all the basic operations of organic chemical experiments are involved in undertaking the two sections to help students review the basic knowledge of organic experiments by completing these two parts. Moreover, multi-step synthesis can encourage students to focus their attention on each operation step, and to avoid small mistakes so as to succeed in the whole experiment by the end of the semester. The successive arrangement in organic chemical experiments is also effective in training students in the abilities needed for scientific research. This education mode, we believe, will lead to the generation of talented students rather than just skillful ones.

Conclusions

Some of above modifications to the course reflect some of the ideas that I have encountered over the last three months. I believe that it would make students more involved, more interactive and stimulate a deep approach to their learning. In particular, I want to point out that these modifications of the organic chemical experiment make only a small reduction in pollution, but we must let our students build up an environmental awareness from such small increments. I think that doing it is better than not doing it. When I return to China, I will use some appropriate strategies to improve my teaching in organic chemistry and organic chemical experiment courses. Certainly, I will come into contact with some difficult problems in the process, but I will try to modify my teaching step by step and make successive improvement in my lectures.

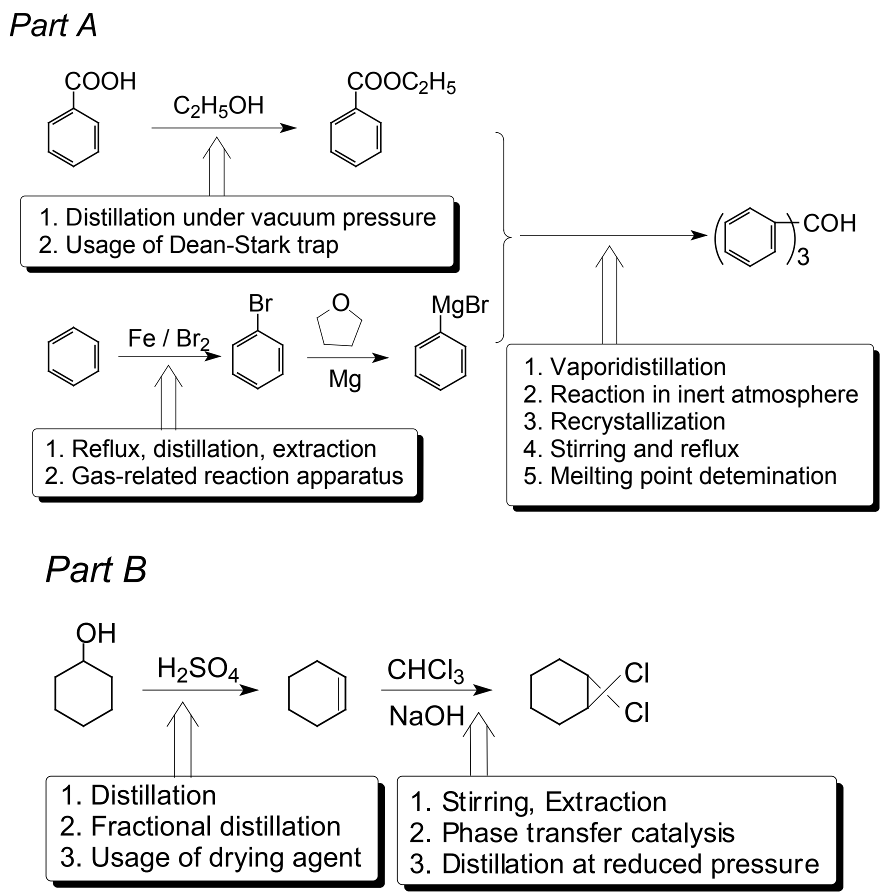

Figure 7. Multi-step synthesis

Acknowledgements

This paper was written while I was visiting the Faculty of Education and the School of Chemistry at the University of Sydney, supported by the China Scholarship Council. I would like to gratefully acknowledge the support from the University of Sydney, Faculty of Education, Faculty of Science and the School of Chemistry. I wish to extend my warmest thanks to Associate Professor Mike King, Associate Professor Mary Peat for introducing me to the field of contemporary education theory, and to Associate Professor Tony Masters, Dr Siegbert A Schmid, Dr Adrian George and all the teachers in this program for their lectures, their help and encouragement, especially to Associate Professor Tony Masters for reading and correcting this paper and for being most helpful and constructive in his criticism. Thanks are also due to my colleagues, for the wonderful days in Sydney, especially to Professor Xu Jianing and Associate Professor Wang Yuzhi, for their help, encouragement and sharing their ideas about the contemporary teaching methodology in science education.

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