How to increase active learning in *Structural Chemistry*

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Abstract

Based on the need of the learner and the characteristics of the *Structural Chemistry* course, the teaching and learning styles of this course have been reconsidered. Both traditional lectures and contemporary education strategies are used to stimulate student's learning interest and to make *Structural Chemistry* more exciting as well. The aim of this paper is to create an active-learning environment in the classroom, to stimulate students' learning interest and to cultivate independent lifelong learners.

Background

Structural Chemistry studies the structures of atom, molecules and crystals at atomic and molecular levels, and furthermore explores the relationship between properties and structures. It is taught to undergraduate students at the third year in Ocean University of China and normally in most Chinese science universities. We have four lecture hours per week, totaling 72 hours through one semester.

The main content of *Structural Chemistry*:

Chapter 1	Introduction to Quantum Mechanics
Chapter 2	Atomic structure
Chapter 3	Structure of Diatomic Molecules and Chemical Bond Theory
Chapter 4	Molecular Spectra
Chapter 5	Molecular Symmetry
Chapter 6	Structure and Properties of polyatomic molecules
Chapter 7	Structure of Coordination compound
Chapter 8	Crystal Lattices and X-ray crystallography

Structural Chemistry is a key to understanding the microcosm, however it is foreign to undergraduate students. It contains fundamental knowledge of quantum mechanics, many inexplicable theories and strange phenomena which are quite different from our visible world. All these lead to a loss of engagement with the content by the learner and hence diminish the learning outcomes.

The theoretical course is always perceived as difficult for a learner who lacks strong learning motivation. And the students quickly lose interest in learning the course. This is especially common when only surface learning is required.

Most students think it is the most difficult course in chemistry. Some students complain that the course is very abstract and cannot comprehend its future usefulness. They conclude it is meaningless to learn the course. All these questions force me to reconsider the teaching and learning in this course.

To find out what the problem is, the following aspects should be considered:

- content: more stress is put on foundation and abstract theories: it is hard for students to perceive their applications;
- teaching: teaching methods are the traditional teacher-centred, lecture, spoon-fed style, most class time is spent with the instructor lecturing and the students listening and taking notes; and
- assessment: assessment methods place too high a premium on memory and recall.

As a consequence, students feel bored, with little interest or motivation. Passive and surface learning are involved. It is my duty to organise the course to change the actuality to increase the interest of my students.

Mentor
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Teachers changing their teaching methods need first to consider the content and characteristics of the course itself. At the same time, teachers should pay more attention to increasing the learners' interest and to transform the learning to deeper and deeper levels.

Methods

Develop a *WebCT* page for this course

During studying at the University of Sydney, I realised that *WebCT* is a very helpful multifunctional tool which plays a very important role in encouraging student learning. It is very convenient for student to get resources related to a certain lecture. It also provides a platform for student to read, talk, write meaningfully, and do quizzes and self-assessment. Being strategically employed, students can be engaged in the learning process. I will develop a *WebCT* page as shown in Figure 1 to help students learn structural chemistry. Before I start the lecture, I will provide a skeletal outline of the lecture content, a list of questions to be discussed in class, lecture notes and necessary references on *WebCT*.

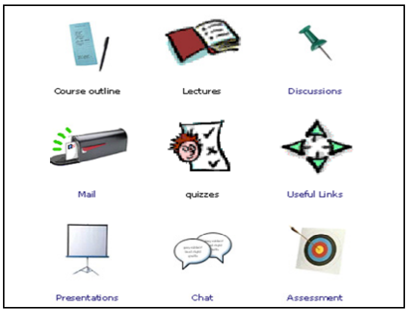

Figure 1. A course page in *WebCT* (King 2006)

Enhancing the lectures' interest

Provide clear lectures

It is imperative that teachers provide lectures that are as clear as possible so that students can make sense of what is being presented. Understanding allows students to retain, recall and apply material in other circumstances. Failure to understand often leads students to incorrectly interpret material or, in frustration, to ignore what has been said (Chilcoat 1989).

Show magic

It is an effective way to gain students' attention and motivate them to learn. Aim to bring students into the sphere of your topic. During the introduction of fundamental knowledge of quantum mechanics, I will tell students the story of how Dirac could foretell the existence of antimatter. Before I give a lecture on molecular spectrum, I will show them a picture of the Blue Mountains and ask why the Blue Mountains look blue (Masters 2006).

Introduce an application

The aim is to remove the doubt of students, as to how this course can be used in future. I will add examples of applications in each topic to show how knowledge plays an important role in science and technology, and how these technologies help us to open the gate to the microscopic world. Therefore, our understanding of nature can go far deeper.

Scientific articles and historical materials

Using scientific articles and interesting historical cases to introduce some basic information about the contents will be useful and helpful in supporting the explanation in the lectures. It also has a value for the lecturer to lead the learner into thinking about what the physical chemist had thought in the past, which is the best way to help students think about the scientific method and so develop their academic thinking skills. For example, Crystal Field Theory was used to successfully explain the structure and colour of coordination compounds. I will ask how was the spin of the electron discovered?

Integrate active learning in classroom

Active learning shifts the focus of instruction from what you, the instructor, should deliver to students, to what do you want students to be able to do with the course material (Center for Teaching and Learning: Florida State University 2006). Confucius' aphorism: I hear and I forget, I see and I remember, I do and I understand.

Research supports the claim that students learn best when they are engaged with the course material and actively participate in their learning. When students learn actively, they retain more course content for a longer time and are able to apply that material in a broader range of contexts.

Even lecturing, which may seem to be inherently passive, can be an active learning experience by simply asking questions.

One useful strategy is to open the lecture with a question and give students a moment to think about their response. This strategy is an easy way to focus students' attention on the day's topic. It also provides the instructor with useful feedback on what students know and don't know about the material being presented. During pauses in the lecture, students may be asked to jot down questions. The following lecture may then begin with these questions, which can function as connectors from the previous class to the present class. Students are periodically asked throughout the lecture to make connections between the current material and course materials covered previously.

Activities for individuals

Submitting questions

1. Ask students to write down and submit any questions they have at the end of each class. The answers to these questions become the beginning of the next class.
2. Stop during the lecture and ask students to write a short list of everything they know about the topic or a sub-topic.

This technique can help students remain attentive and provide feedback to you about the students' knowledge or misunderstandings. It also provides a way to review course material before moving forward.

Activities for groups

Recent research suggests that individuals in small groups learn better than they do on their own or in isolation. Small groups initiate collaborative learning and its resulting activities: students generate questions, discuss and arrive at conclusions.

Think-pair-share

'Think-Pair-Share' is an active learning strategy that engages students with material on an individual level, in pairs, and finally as a large group. This activity starts with each student working individually on a problem for a short time; then students pair to compare, synthesise, and finish the assignment. This can be expanded to create a pyramid when those two students work with two more. Later they report to the whole class (Lymna 1981).

Question and answer pairs

'Question and answer pairs' is an exercise in which teams of students practice asking and answering challenging questions. Each student takes a minute to formulate one question based on the information presented in the lecture or course readings. Student A begins by posing her question for student B to answer. Then the roles are reversed, with student B becoming the questioner.

Good questions can be used on practice examinations. The strategy is particularly useful for teaching students how to frame good questions. It can also be used to encourage students to prepare questions based on their reading.

Problem-based learning

Problem-based learning (PBL) begins with a problem prepared by the instructor that generally cannot be easily solved without data collection and mastery of subordinate skills. Students search for resources, and/or faculty members guide students to information and resources. Instructors help students learn to frame the right questions, formulate problems in clear and organised language, explore alternatives, and make effective decisions.

PBL is a curriculum design and a teaching/learning strategy. 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; and 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).

Since PBL is a relatively new approach in teaching structural chemistry, it is challenging to both students and the teacher. At the beginning, I would like to choose one or more simple problems in several topics. Students will work in groups of four.

An example for PBL

The addition reaction of ethylene with hydrogen is:

$$C_2H_4 + H_2 \rightarrow C_2H_6$$

$$\Delta H = -137.3 \text{ kJ•mol}^{-1}$$

This is a very simple addition reaction, however it can not occur without a catalyst, why?

To solve the problem, students must use self-directed learning to gain the following knowledge of structural chemistry:

- molecular orbit;
- frontal molecular orbit;
- the shape and symmetry of HOMO and LUMO; and
- frontal orbital theory.

After group discussions, finding the relevant knowledge and thinking independently, students may find a path like that illustrated in Figure 2.

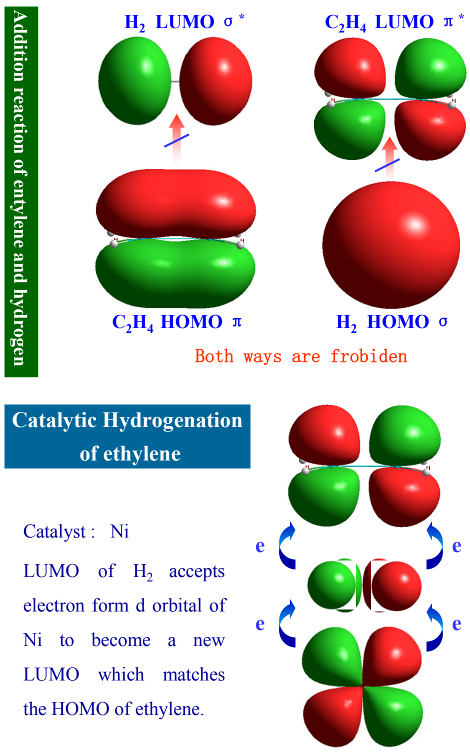

Figure 2. Addition reaction of ethylene with hydrogen

Case studies

Case studies are different from PBL in that they are much more specific, more highly focused and well defined. They give real and complete stories with messages and questions, and teach through those stories. The case usually has both academic significance and social application (King 2006). A good case study should be interesting, relevant, motivating, integrating many disciplines and related to the real world.

In a case study, students must spend some time studying independently, and learn to work both individually 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.

Following is a case study about the possible structure of O_4: Elements oxygen and sulfur are in the same group. Generally, a sulfur molecule is composed by eight sulfur atoms. However, oxygen molecules contain two or three oxygen atoms as shown in Figure 3. O_8 molecule is not detected yet. Only O_4 was reported to be detected but has a short life. Please use chemical bond theory to design the possible structures of O_4.

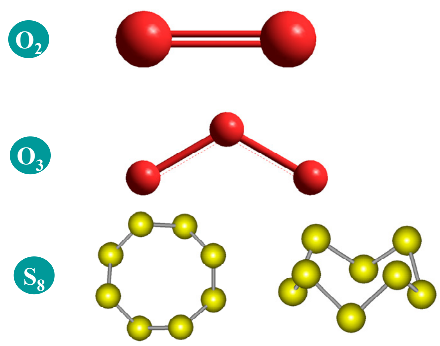

Figure 3. Stable structure of oxygen and sulfur molecules

Students must consider facts to solve the problem:

- as a covalent compound, how many bonds can an oxygen atom form?
- characteristics of covalent bond;
- bond energy of single, double and triple bonds; and
- the relationship between bond energy and bond order.

Through collecting information, thinking, discussing, reading, and studying, students would improve their understanding of many basic concepts and principles of organic chemistry. Most importantly, students would understand how to apply the knowledge delivered by the instructor.

Conclusion

Traditional teaching approaches used in *Structural Chemistry* should be improved without hesitation. The combination of high-quality lectures and some contemporary teaching strategies can be used to improve active learning in this course. I expect to achieve the following:

- improve the quality of teaching;
- enhance the lectures interest;
- increase the students' motivation;
- increase students' interest in learning structural chemistry; and
- develop some important abilities and skills in students such as problem solving skills, critical thinking abilities, creative abilities, lifelong learning abilities, etc.

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