Comparison of the chemistry practical work at The University of Sydney and Zhejiang University

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Abstract

A comparison between the chemistry practical work at The University of Sydney and Zhejiang University is given. A simple introduction to the practical workshop at the National Chemistry Experimental Teaching Center (NCETC) of Zhejiang University is given. New reforms and modifications to demonstration strategies are also described.

Introduction

Chemistry as a central science is the largest branch of science. Many aspects of other scientific disciplines, such as biology, botany, medicine, pathology and veterinary science, are increasingly involved with chemistry. Work on pollution control, global warming, environmental protection, conservation of resources, alternative energy sources, modern medical treatments, new materials and many other industries depend strongly on the chemical properties of matter [1-5].

Chemistry is a practical science. The laboratory work is an essential part of all chemistry units of study at the university level.

The teaching laboratories of the School of Chemistry at The University of Sydney are the best teaching laboratories in Australia. The NCETC at Zhejiang University is among the top five in China. Therefore there is value in a comparison between the chemistry practical activities at these universities.

History of the Chemistry Experimental Teaching Center of Zhejiang University

In 1985, the Department of Chemistry at Zhejiang University began to reform the chemistry experimental courses. Chemistry experimental courses became independent of lectures and the teaching laboratories became independent of teaching groups. The instruments used in practical work were centralised to be shared by the different experimental courses.

In 1987, the first Chemistry Experimental Teaching Center was established at Zhejiang University in China. Since then, more and more Chemistry Experimental Teaching Centers have been established in other universities.

In September 1998, a new Zhejiang University was established by the amalgamation of four former individual universities, namely Zhejiang University, Hangzhou University, Zhejiang Agricultural University and Zhejiang Medical University, all located in the garden city of Hangzhou. The chemistry teaching laboratories of the other three universities joined the Chemistry Experimental Teaching Center at Zhejiang University which then began a second generation of experimental reforms.

In 2002, a new large building was set up in the Zijingang campus of Zhejiang University for the Chemistry Experimental Teaching Center. ￥6,200,000 was allocated by Zhejiang University to buy and renew instruments for teaching.

In 2006, the Chemistry Experimental Teaching Center of Zhejiang University became one of the National Experimental Teaching Centers.

Comparison in general

A comparison of Chemistry practical work at the School of Chemistry of The University of Sydney and the NCETC at Zhejiang University is given and the

modification of demonstration strategies in chemistry experiment courses at NCETC of Zhejiang University is discussed.

Organisation

The chemistry teaching laboratories at The University of Sydney belong to the School of Chemistry. There are three teaching laboratories: first year laboratory, second year laboratory (including Physical Chemistry Laboratory, Inorganic Chemistry Laboratory and Organic Chemistry Laboratory) and third year laboratory (including Physical Chemistry Laboratory, Inorganic Chemistry Laboratory and Organic Chemistry Laboratory). Each laboratory has a laboratory director who is in charge of the experiments. There are first, second and third year and honours coordinators, who are in charge of the courses (including lectures and practical work) and are on the teaching committee.

The NCETC of Zhejiang University belongs to the Department of Chemistry, Faculty of Science. In the NCETC, there are four teaching laboratories: Fundamental Chemistry Laboratory, Intermediate Chemistry Laboratory, Advanced Chemistry Laboratory and Instrument Platform (for all the undergraduate students and research measurements). The NCETC is chaired by the Vice Dean of the Faculty of Science with two coordinators in charge of experimental teaching and instruments organisation. Each laboratory has one director who organises the daily work of the laboratory and one to four instructors organising all the experiments running in the laboratory. All the experiments are independent of the lectures. The coordinator in charge of experiment teaching is on the teaching committee of the Department of Chemistry.

Number of students doing chemistry experiments

The numbers of students doing chemistry experiments at The University of Sydney and Zhejiang University are listed in Table 1. From Table 1, it is clear that the number of students doing chemistry experiments at Zhejiang University is larger than at The University of Sydney. This is because students in many general engineering majors are required to do chemistry experiments at Zhejiang University, and because the students in the faculties of chemical engineering, material science, medicine and food engineering are required to undertake chemistry experiments.

Table 1. Number of students doing chemistry experiments

USyd*	**First year**	**Second year**	**Third year**
	~2000	400-500	~100
ZJU*	**Fundamental**	**Intermediate**	**Advanced**
	~3500	~900	~300
Students in Chemistry	~100	~100	~100

*(USyd is The University of Sydney and ZJU is Zhejiang University)

Chemistry practical work

A comparison of the practical work undertaken at The University of Sydney and Zhejiang University is given in Table 2.

The Advanced Chemistry Laboratory at the NCETC is an open-laboratory and is open from Tuesday to Saturday (8 am–9 pm). The advanced chemistry experiments consist of two parts: workshops and projects (workshops are some of the research results in the Department of Chemistry and projects are the successful workshops: all are close-ended problems). Students work in pairs. There are two or three seminars each semester. When the students commence workshops, they must undertake searches, review literature related to the topics they select, give oral presentations on the design of their proposed experiments, and then discuss these proposed experiments with other students and the demonstrators. If the demonstrator thinks that the designs are workable, the students can conduct trials in the laboratory. During the experiment process, they can change their designs until they get satisfactory results. Students are encouraged to work in teams. For the same project or workshop, different groups can do experiments under different conditions such as temperature and time. They can get different results and share them. The reports should be written in the format of research articles.

In the Intermediate Chemistry Laboratory, students are required to answer questions on research work or engineering applications of the techniques used in the experiments and then practice them in the laboratory, although some of the experiments are classical. The students must think independently and put the theory into practice. For example, using the bomb calorimeter is a classical physical chemistry experiment. The heat of combustion of naphthalene is usually measured in this experiment. After finishing the measurement, the students will be required to think about how to measure:

1. the heat of liquid fuels;
2. the heat of combustion of fractions of crude oils;
3. the amount of sulfur in fuels or solid wastes;
4. the heat of combustion of sugar, milk, etc.; and
5. the heat of biomass, soils from different places, such as those from the West Lake, and lakes at different campuses of Zhejiang University.

All these problems are related to energy, biology and the environment. The students are usually very interested in them, and they will learn how to solve a new problem with an old method through the experiment.

During the whole semester, the students are shown to understand:

1. the difference between teaching laboratory and research laboratory;
2. the similarity between some experiments in the Intermediate Chemistry Laboratory and the research work being done at the Department of Chemistry or engineering applications, such as distillation of crude oil, supercritical extraction, etc.; and
3. how to solve problems in engineering or real life.

One objective is to show the students the relationship between the intermediate Chemistry experiments and the research work they will meet afterwards, and improve their critical thinking skills and problem solving skills.

Table 2. Comparison of the chemistry practical work at The University of Sydney and Zhejiang University

USyd		ZJU Chemistry major	
First year laboratory	**Mixed experiments** 10 experiments, 3 hours/week Two semesters Work in pairs or individually	**Mixed inorganic and analytical chemistry experiments** 15 experiments, 5 hours/week Two semesters	**Fundamental Chemistry Lab**
		Organic chemistry experiments 15 experiments, 6 hours/week Second year semester 1 Work individually	
Second year laboratory	**Semester 1** **Chem2401 (Core Unit)** 8 four-hour practical sessions (Quantitative analytical experiments and Organic chemistry experiments) Work individually **Chem2404 (Elective unit)** 5 four-hour practical sessions Work in pairs	**Second year semester 2** **Instrumental analytical experiments** 15 experiments, 4 hours/week Work in pairs	**Intermediate Chemistry Lab**
	Semester 2 **Chem2402 (Core Unit)** 8 four-hour practical sessions (Physical/ Theoretical chemistry experiments (work in pair) and Organic chemistry experiments (Work individually)) Chem2403 (Elective Unit) 5 four-hour practical sessions Work individually	**Third year semester 1** **Physical chemistry experiments** (15 experiments, 6 hours/week Work individually	
Third year laboratory	**Inorganic** (5 instrumental experiments and 2 normal experiments) **Organic** (4 experiments) Work individually **Physical** (4 experiments or 1 project) Work in pairs **One workshop** Two sessions/week, 6 weeks, two semesters Laboratory practices	**Projects and workshop** (all mixed)(2 projects, 4-5 workshops) (at least 6 hours/week)Work in pairs, sometimes in groups	**Advanced Chemistry Laboratory**

Furthermore, the **talented students** are required to finish the following work:

1. additional part of reports: review of the literature on the topic in which they are interested;
2. design of some more demanding experiments; and
3. more experiments.

Assessment in practical work

The assessments in practical work at The University of Sydney and Zhejiang University are quite different. The comparison of the assessment in practical work is listed in Table 3.

Table 3. Comparison of the assessment in practical work at The University of Sydney and Zhejiang University

	USyd	ZJU (Chemistry major)	
First year Laboratory	1. Online pre-work and quiz 2. Attitude/attendance/post-work 3. Practical exercise	1. Pre-laboratory work 2. Performance in the laboratory 3. Experimental results 4. Practical reports	**Fundamental Chemistry Laboratory**
Second year Laboratory	1. Performance in the laboratory 2. Quality and yield of the compound or accuracy of experimental results 3. Practical reports	1. Pre-laboratory work 2. Performance in the laboratory 3. Experimental results 4. Practical reports 5. Written examination	**Intermediate Chemistry Laboratory**
Third year Laboratory	1. Performance in the laboratory 2. Quality and yield of the compound or accuracy of experimental results 3. Practical reports 4. Oral examinations (Inorganic and Physical)	1. Pre-laboratory work 2. Performance in the laboratory 3. Experimental results 4. Practical reports 5. Oral examination 6. Written examination	**Advanced Chemistry Laboratory**

Table 4. Generic skills undergraduate students should increase

Generic skills	USyd			ZJU		
	First	Second	Third	Fundamental	Intermediate	Advanced
Knowledge	✓	✓	✓	✓	✓	✓
Application of theory to practice	✓	✓	✓	✓	✓	✓
Critical thinking and judgment	✓	✓	✓	?	✓	✓
Teamwork	✓	✓	✓	?	?	✓
Communication	✓	✓	✓	Not as much as at USyd		
Experimental skills	✓	✓	✓	✓	✓	✓
Safe working practice	✓	✓	✓	Very little		
Numeracy and use of technology	✓	✓	✓	✓	✓	✓
Self-management	✓	✓	✓	?	✓	✓

Generic skills

Both universities require the students to improve their generic skills through doing chemistry experiments. Some of the generic skills required at The University of Sydney and Zhejiang University are compared in Table 4.

From Table 4, we can see that the NCETC of Zhejiang University should pay more attention to the skills of communication and safe working practices for the students.

Student feedback

At The University of Sydney, there are Unit of Study surveys for the structure and content of the chemistry units, and teaching surveys for individual lecturers. There are no special surveys for practical work, however some chemistry teaching laboratories have their own surveys for the practical work. For example, the third year Inorganic Chemistry Laboratory has a questionnaire on the workshop.

At Zhejiang University, students are required to give their feedback and evaluation of the experiment courses at the end of the semester. Some of the teaching guides and academic staff from the department and the Faculty of Science will also give their feedback of the experiment courses. According to the feedback and evaluation, some experiments will be changed and the demonstrators will also be changed if they do not work effectively.

Problems

Although the NCETC of Zhejiang University is attempting to help undergraduate students to improve the generic skills needed by chemists, some problems still exist. For example, the talk at the beginning of each experiment session is mostly teacher-centred. None of the experiments are open-ended. There is little pre-laboratory work, especially for the first year students. There is very little online material for the students to read before and after the experiment session. There is very little instruction in safe working practices.

Most of the demonstrators think that the responsibility for learning lies with the teachers not the students. After Associate Professor Mike King's lecture on teaching theories [6], I question that belief. Generic skills: critical thinking skills, active learning skills, independent learning skills, problem solving skills, communication skills (both oral and written), ability to see relationships, independent judgment, critical self awareness and lifelong learning skills.

Modification of demonstrating strategies

Since 2006, first year undergraduate students of Zhejiang University do not major in chemistry, but are in the Faculties of Science, Engineering, Culture, Medicine or Agriculture.

To attract more students to study chemistry, we must reform our practical work again. This time our aims are to:

1. continue to develop flexible, modern facilities and processes for learning chemistry's core practical elements;
2. seek to transform the student experience of practical chemistry;
3. help students to improve their level of generic skills effectively;
4. set a new standard for the laboratory-based learning of science; and
5. create a major national resource for teaching and learning practical experimental science.

In order to meet the above aims, we must:

1. change our demonstrators' teaching ideas;
2. use new demonstration strategies with students at different levels of practical work;
3. replace some boring experiments with new more exciting ones which are much closer to real life and engineering applications, while still covering the experimental skills that a chemist needs; and
4. help the students to improve their levels of generic skills effectively.

Change our demonstrators teaching ideas

These teaching ideas are:

- the responsibility for learning is the learners' not the demonstrators';
- 'Chemistry is doing'; and
- 'life is Chemistry'.

New demonstrating strategies can be used at NCETC of Zhejiang University

In the different chemistry laboratories, we can use different demonstrating methods.

In the Fundamental Chemistry Laboratory, we can:

- use more student-centred demonstrations and more multimedia demonstrations;
- give students more pre-laboratory work and more online materials to read;
- conduct more discussions after the experiment session; and
- concept maps to help students to learn more theoretical and practical knowledge.

In the Intermediate Chemistry Laboratory, we can:

- prepare more projects and workshops;
- prepare more industry context experiments-workshop, and case studies;
- give more instruction in safe working practice; and
- have more discussion before and after the experiment session with the students.

The two projects the third year students do in the Physical Chemistry Laboratory are very good projects for our students. One is the solar cell, and the other is biodiesel [7], and I think I will introduce them into our intermediate chemistry experiments.

Here are two cases that I found on the Web [8-9] which are suitable for students who are studying thermodynamics.

Fuels and Society Chemistry and History of Automotive Fuels [8]

> *It is early in the 20th century and the nation has a system problem. People want automobiles and want fuels to power them. The supply and quality of the fuels limit the automakers' abilities to make large numbers of automobiles with powerful, efficient engines.*
>
> *The Questions: How did research along three parallel pathways lead to a number of solutions to the problem of poor quality and insufficient quantity of gasoline. Students will go through a series of units outlined in the concept map and end with a case discussion on how they would have dealt with the issues of gasoline quality and supply that faced automakers, oil companies and the government in the early 20th century.*

Burning Down the House: A Case Study in Forensic Instrumental Analysis [9]

> *In this laboratory-based case, arson investigator Marie Stanforth comes under suspicion when her ex-husband dies in a fire. Students read the case and then, in the role of forensic chemists working for the FBI, analyse charred samples recovered from the crime scene as well as a clothing swatch taken from the principal suspect, comparing what they find in the samples to accelerant standards whose spectra are already known. Once they have determined whether or not the fire was arson, they must then determine if the allegations against Marie are credible.*

In the Advanced Chemistry Laboratory, we can also try:

- more industry context or real life experiments and workshops;
- problem-based learning (PBL);
- safe working practice; and
- encourage the students to give more oral presentations and so improve their communication skills.

Why PBL in the Advanced Chemistry Laboratory?

'Learning science is something students do, not something that is done to them.' PBL provides instructors with a tool to enable students to learn science [9]. Students in the Advanced Chemistry Laboratory are third year students and have a good knowledge of chemistry and they have already done some research work when they are doing the SRTP (Student Research Training Program).

A PBL case which can be tried in the Advanced Chemistry Laboratory is [10]:

> *You are currently employed by a major manufacturer of soaps and detergents. The company has spent several years in the development of a new product. This new product is almost ready to go to the market. However, before introducing the product to the public, management has requested one more set of tests. Your team has been asked to do a blind test on the product alongside several major competitors. They want to ensure that the prior data collected are not biased. You will not know which sample is the new product and which samples are other major selling soaps and detergents. Your results will be reported back to management who will then determine if, in fact, the new product has lived up to expectations. In order to ensure that your work is replicable, you are asked to follow recipes and protocols that the company has developed for testing soaps and detergents. These recipes and protocols will be provided to you.*

Change of experiments

Some boring experiments can be replaced by some more exciting ones such as virtual laboratory experiments, computational-aided experiments, new experiments related to engineering applications and real life (some can be open-ended problems), more projects or workshop in the intermediate chemistry laboratory and teaching more safe working practice.

Through the modification of demonstrating strategies and change of some of the experiments, we will try to help students to improve their generic skills through doing chemistry experiments. These generic skills include critical thinking skills, active learning skills, independent learning skills, problem solving skills, communication skills (both oral and written), the ability to see relationships, independent judgment, critical self awareness and lifelong learning skills, etc.

Conclusion

In this paper, a comparison of the chemistry teaching laboratories of The University of Sydney and the NCETC

of Zhejiang University is given, and the chemistry practical work of Zhejiang University is introduced. Some modifications of the demonstrating methods to improve the students' generic skills at Zhejiang University are also described.

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