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Comparison and Analysis to Labwork of Chemistry Textbooks of High School between Beijing and Taiwan from the Perspective of Science Literacy

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Abstract

Chemistry is an important part of science, and labwork is the central part in teaching the course of chemistry in high school. With the aim of analyzing labwork of chemistry textbooks in high school in Beijing and Taiwan and on the basis of ‘A map of labwork’ in Labwork in Science Education (1998) working paper 1 and working paper 3, this study emphasizes on comparing and analyzing the learning objective and features of task. In the study we use the definition of science literacy in PISA framework 2009 to analyze the chemical experiment designed in the laboratory manual. Under one guiding principle there are various chemistry textbook editions in Taiwan. We use the Hanlin (HL) edition recommended by high school teachers of chemistry in Taiwan as a research object and compare them with those published by the People’s Education Press (PEP) used by most of the high schools in Beijing. Through the comparison and analysis of the intended learning objective and features of task, teachers will come to a better understanding of what kind of influence their teaching of chemistry experiments can make on students’ learning of chemistry and on their future development.

Keywords: Labwork, high school chemistry curriculum, Science literacy

Introduction

Beijing and Taiwan have very similar cultural background and use the same language, but still there are differences in some areas. For example, in the field of chemistry education of high school, the formulation of curriculum criterion is subject to influences from the differences. After the new round of high school chemistry curriculum reform carried out by Beijing in 2007, the new chemistry textbooks published by People’s Education Press (PEP) have played an essential role on improving science literacy of students and promoting their comprehensive development. Taiwan has made gratifying results in the tests of Program for International Student Assessment (PISA) carried out by Organization for Economic Co-operation and Development (OECD) and Trends in International Mathematics and Science Study (TIMSS) carried out by the International Association for the Evaluation of Educational Achievement (IEA), which examined comprehensively the science literacy of students, and measured the capabilities they need in making decisions related to science and technology in the future.[1,2]

We use A ‘map’ of ‘labwork’ from "Labwork in Science Education" by Millar *et al*. [3]

to make a comparison. Also, the definition of science literacy in this research is quoted from PISA 2009 science framework.

High school teachers both in Beijing and Taiwan are also invited to analyze the experiments. The framework of the research is shown in Figure 1. [3]

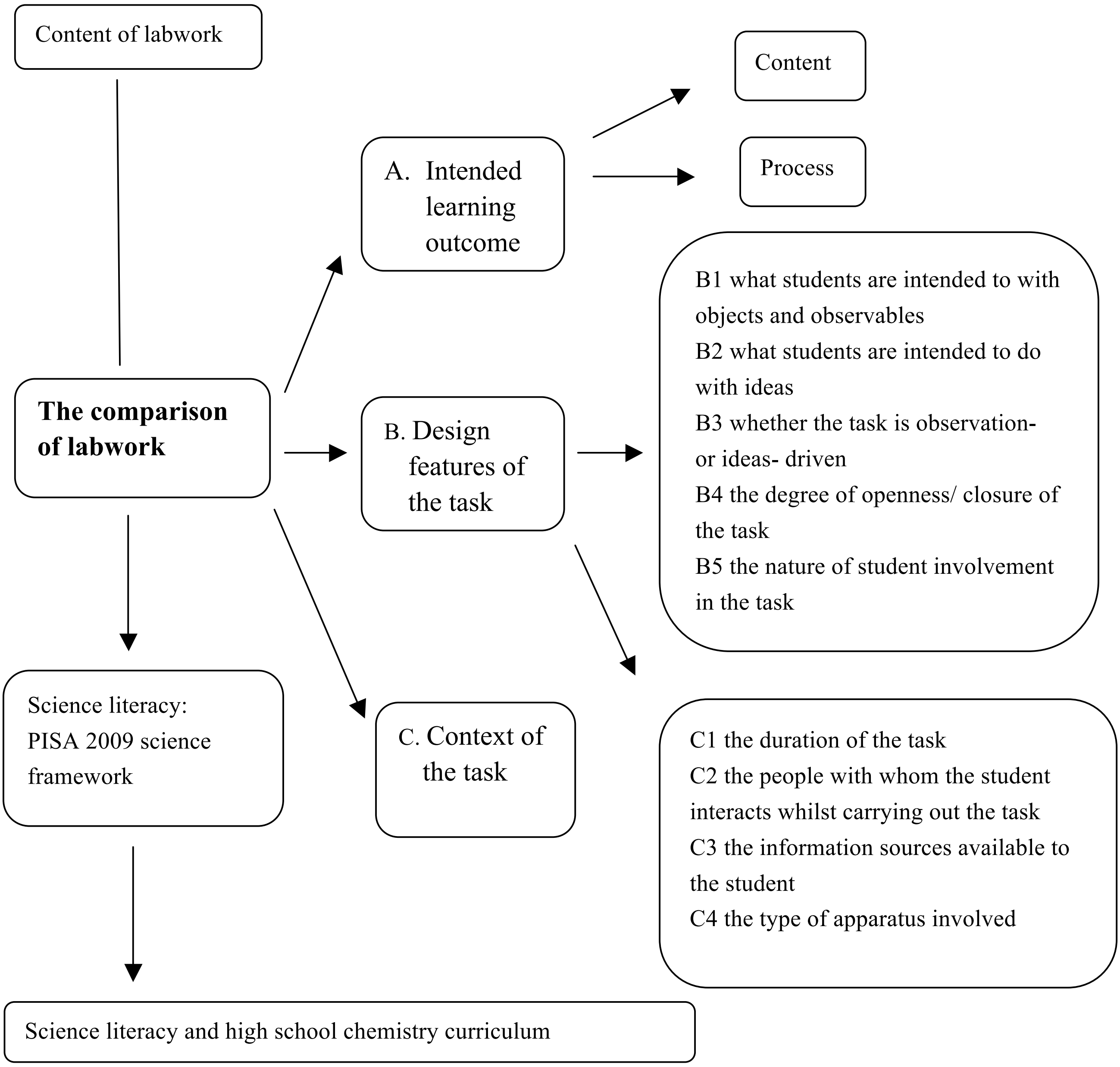

Figure 1. Framework of comparison

Table 1. Contents of chemistry laboratory manual of PEP in Beijing [4, 5]

Contents of compulsory chemistry textbooks by PEP	
Compulsory chemistry 1	Compulsory chemistry 2
Chapter 1 Learning chemistry through labwork	Chapter 1 The structure of matters and periodic law
1. Filter and Evaporate 2. Preparation of distilled water in the lab 3. Extraction and dispensing 4. Scientific inquiry: The volume of 1 mol substance 5. Configuration solution with certain concentration	1. The property of alkali mental 2. Substitution reaction between halogens 3. Periodic trends 1 4. Periodic trends 2 5. The reaction between Na and Cl_2
Chapter 2 Chemical substance and its change	Chapter 2 Chemical reaction and energy
6. The property of colloids 7. Ion 8. Condition that ions reaction occur	6. Chemical energy and heat 7. Chemical energy and electricity 8. The choice of material of voltaic cell 9. Factors that affect chemical reaction rate
Chapter 3 Metal	Chapter 3 Organic compounds
9. The property of Na and Al 10. The protective membrane covering Al 11. Can Fe react with water vapor? 12. The property of Na_2O_2 13. The property of Na_2CO_3 and $NaHCO_3$ 14. Flame reaction 15. The preparation and property of $Al(OH)_3$ 16. $Fe(OH)_3$ $Fe(OH)_2$ examination of Fe^{3+} 17. The property of molysite	10. The substation reaction of CH_4 11. The chemical property of C_2H_4 12. The property of benzene 13. The property of ethanol 14. The acidity of acetic acid 15. Etherification 16. The property of carbohydrate and protein
Chapter 4 Non-metal	Chapter 4 The development and utilization of natural resource and chemistry
18. The preparation of H_4SiO_4 and the property of Na_2SiO_3 19. The chemical property of Cl_2 20. The examination of Cl^- 21. The property of SO_2 22. The reaction between NO_2 and H_2O 23. NH_3 24. The reaction between H_2SO_4 and Cu	17. Thermite reaction 18. Obtain iodine from kelp

Table 2. Content of chemistry laboratory manual of Hanlin in Taiwan [6-8]

Content of foundational chemistry by Hanlin Press in Taiwan	
Foundational chemistry 1	
Chapter 1 The composition of matter	Chapters without experiments
1. Demonstration experiment: ways to classify reaction	Chapter 2 The structure and property of atom
2. Separation and purify of the mixture	
Chapter 4 Common chemical reaction	
3. Dissolution and crystallization of KNO_3	Chapter 3 Chemical reaction
4. Chemical energy and Heat	
Foundational chemistry 2	
Chapter 1 The structure and property of matter	
5. Demonstration experiment: 3D model of molecular	
Chapter 2 Organic compounds	
6. The general property of organic	
Chapter 3 Energy and chemistry	
7. Batteries	
Chapter 4 chemical energy and chemistry	
8. Effect of surfactant	
Foundational chemistry 3	
Chapter 2 Chemical reaction rate	Chapter 1 Gas
9. Chemical reaction rate	
Chapter 3 Chemical equilibrium	
10. Determination of equilibrium constants	
11. Demonstration experiment: Le Chatelier’s principle	
12. Determination of *Ksp* (solubility product constant)	

Content of labwork

Chemical labwork is an important part of chemistry learning, and the contents of labwork and chemistry textbooks are closely related. Here we give a brief account of the contents of labwork and chemistry textbooks both in Beijing and Taiwan, as shown in Table 1 and Table 2.

There are two compulsory textbooks containing eight chapters, 42 experiences and six other selected textbooks published by PEP in Beijing; it takes one school year for Beijing students to learn the two compulsory textbooks. [9]And there are three foundational textbooks containing 11 chapters, 12 experiences and two other selected books published by Hanlin Press in Taiwan. It takes Taiwan students two school years to learn the three foundational textbooks. [10] The content of selected textbooks is not taken into consideration. Beijing students have much more labwork classes than Taiwan students do.

PEP 1 means the compulsory chemistry 1 published by People’s Education Press; and PEP 2 means the compulsory chemistry 2 published by People’s Education Press. HL 1 means the foundational chemistry 1 published by Hanlin Press, HL 2 means the foundational chemistry 2 published by Hanlin Press, and HL 3 means the foundational chemistry 3 published by Hanlin Press.

Dimension A: Intended learning outcome (learning objectives)

The teaching or learning tasks generally start with the establishment of the learning objectives by teachers, which leads the teachers to make further teaching plans to achieve the goal. In this part, chemistry experiments in high school textbooks are classified according to the specified experiment objectives. The learning objectives are classified into two categories, one is about the learning of science content and the other is about the processes of scientific enquiry. [3] Further classifications are shown in table 3.

In A-b, a ‘fact’ means factual knowledge of chemistry, which is closely related to the quality of substances, and reflects a wide-ranging knowledge such as the presence, manufacturing method, preservation, utilization, test and reaction of substances. Factual knowledge in chemistry consists of two major parts, knowledge of inorganic elements and compounds and knowledge of organic compounds.

In A-d, a 'relationship' might be a pattern or regularity in the behavior of a set of objects or substances, or an empirical law, such as Periodic law, the factors affecting the chemical reaction rate, Le Chatelier's Principle and so on. [11,12]

In A-h, ‘To make an experiment design to address a specific question or problem’，is to help students grasp basic scientific methods and apply the scientific methods in chemistry experiments.

e.g. Students design the ‘control variables’ experiment, or learn how to make the ion (Cl^-, SO_4^{2-}) tests. [4]

In A-i, when students need only to process experimental data and calculations, this kind of experiments are categorized A-i.

e.g. *Utilize colorimetry, that is to make iron ions (Fe^{3+}) react with thiocyanate ions (SCN^-), to measure the concentration of the product iron thiocyanate ions ($FeSCN^{2+}$), so as to obtain the equilibrium constant Kc.* [12]

In A-j, the ‘data’ includes both experimental phenomena and experimental data. Students need to record the experimental phenomena and data and explain the experimental phenomena, then come to a conclusion or write down chemical reaction equations. This type of experiments is categorized A-j.

The classification is based on the learning objectives of laboratory manual.

Figure 2 and Figure 3 separately show the learning objectives that are related to the learning content and processes and the percentage of the number of experiments corresponding to the PEP learning materials and HL learning materials under each specific experiment objectives. Through comparison, we can see the main learning objective of chemical experiments is to help students ‘learn factual knowledge’, which includes understanding the properties of substance or the basic principle. In Beijing, helping students ‘learn factual knowledge’ in chemistry experiment courses, which means the learning of properties of substances or materials, takes a large percentage of all labwork, as shown in Table 1. However, the main purpose of doing chemistry experiences in Taiwan is to help students ‘learn a concept’, such as dissolution, crystallization, or solubility product constant, as shown in Table 2.

The learning objective related to the process, both in Beijing and Taiwan, is to help students share their reports or have better discussions, for students are required to accomplish their experimental reports and write down the experiences they gain through the experiments. Also, the textbooks emphasize on helping students both in Beijing and Taiwan 'learn how to use data to support a conclusion'. As for the requirements to students, there are differences between Beijing and Taiwan. The students in Taiwan need 'to learn how to use rightly a standard laboratory instrument, or to set up and use a standard piece of apparatus', but students in Beijing need 'to learn how to plan an experiment to address a specific question or problem'. Of all the experiments, this type of experiments covers a large proportion. For example, when students in Beijing are intended to design the experiments to inquire the substation reaction of CH_4, they must learn how to control variables first. [13] In Taiwan, however, when students learn the 'general property of organics', one of the learning outcomes is to learn the 'use of a dropper and a cylinder correctly'. [7] Also, it is significant that students in Taiwan learn 'how to process data' through labwork.

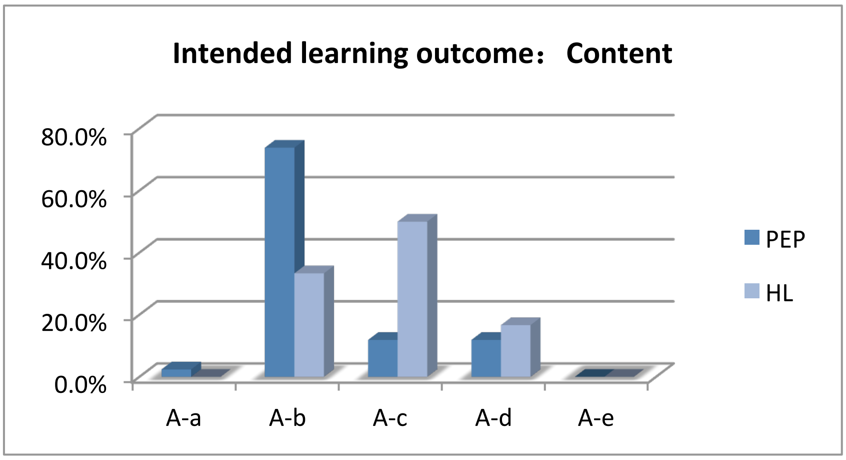

Figure 2. Learning objectives related to the content by discipline (see Table3 for the meaning of items)

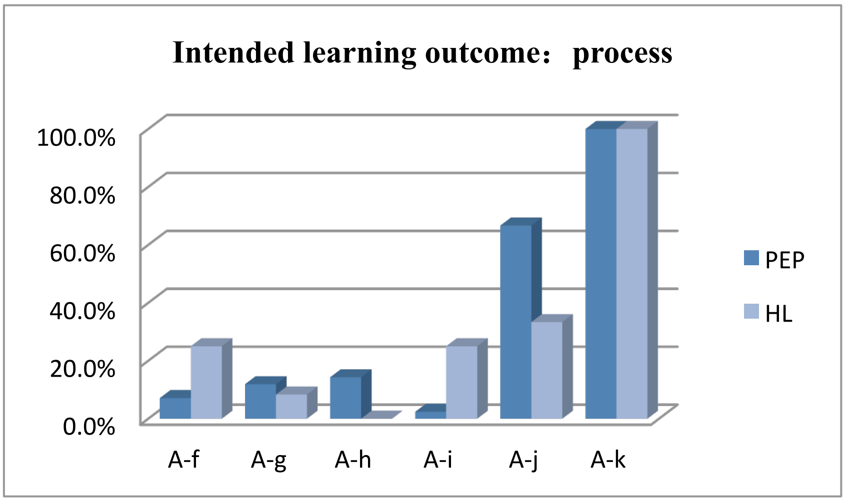

Figure 3. Learning objectives related to the process by discipline (see Table 3 for the meaning of the items)

Table 3. Items related to the intended learning outcome (learning objective) [14]

Content	Process
To help	students to:
A-a to identify objects and phenomena and become familiar with them	A-f to learn how to use a standard laboratory instrument, or to set up and use a standard piece of apparatus
A-b to learn a fact or facts	A-g to learn how to carry out a standard procedure
A-c to learn a concept	
A-d to learn a relationship	A-h to learn how to arrange an investigation to address a specific question or problem
A-e to learn a theory/model	A-i to learn how to process data
	A-j to learn how to use data to support a conclusion
	A-k to learn how to communicate the results of their work

PEP means the experiments shown in chemistry laboratory manuals by People's Education Press in Beijing, and HL means the experiments shown in chemistry laboratory manuals by Hanlin Press in Taiwan.

Dimension B: Design features of task

The second main dimension of the map aims at characterizing the design features of labwork tasks: what students are intended to do with objects and observables (B1) and what they are intended to do with ideas (B2). [3] The further sub-division is shown in table 4 and table 5.

What students are intended to do with objects and observables (B1)

This sub-dimension of the map (B1) relates to what students are intended to do with objects and observables. [3]

Most labwork tasks involve the student in manipulating and/ or observing objects or materials. Some involve learning how to use instruments rightly, or procedure of basic laboratory operation. The students may be intended to:

- use an observation or measuring instrument (B1-1)

e.g. use a burette to deliver measured volumes of a liquid; [12]

- use a laboratory device or arrangement (B1-2)

e.g. use a volumetric flask correctly to configure a specific concentration of the solution;
use a funnel to separate water and oil. [15, 16]

- use a laboratory procedure (B1-3)

e.g. carry out a recrystallisztion of a compound to produce a purer sample; [15,16]
follow a standard schedule to determine the melting point of a substance.

A different type of task is one which involves learning how to present an object so as to display certain features of it clearly. Here the student is intended to:

- present or display an object (B1-4)

e.g. make a primary battery by selecting appropriate electrode material. [11]

Other tasks require the student to make something. This may be a physical object, or a material. [3]

- make an object (B1-5)

e.g. synthesize a particular chemical substance. [11]

- make an event occur (B1-7)

e.g. esterification: CH_3COOH *reacts with* C_2H_5OH [11]
the property of Na and Al: Na reacts with O_2、H_2O, *Al reacts with* O_2、HCl、$NaOH$ *and so on* [15]

The fourth, and perhaps the largest, category of labwork tasks is those which require the student to observe something. The observation may be of an object or a material. The student may be intended to:

- observe a experiment object (B1-8)

e.g. note and record the general property of organic compounds, includes solubility, odor, color etc. [17]
note and record the physical properties of a sample of polythene. [11]

In other situations, the observation is better characterized as observation of an event. Here the students are required to:

- observe an event (B1-10)

(Demonstration experiments that students are required to record experimental phenomena.)

Finally, the task may involve the observation of a physical quantity (or variable) associated with an object, or material, or event. Such an observation may be qualitative (e.g. an observation of color), or semi-quantitative (noting if something is large, or small), or quantitative (i.e. a measurement). In these cases, the student is intended to:

- observe a quantity (B1-11)

e.g.measure the concentration of an acid solution by neutralizing standard alkali solution; [12]
measure the melting point of a substance;

The analysis is based on the interview to high school chemistry teachers. Also the laboratory manuals and chemistry textbooks which describe the process of each experiment are taken into consideration.

It is significant that students are intended to 'make events occur' both in Beijing and Taiwan. According to the arrangement of the chemistry textbook published by PEP, more than 70% of the experiments are designed to let students make events including reactions occur. However, this kind of labwork in Taiwan's chemistry textbooks published by Hanlin takes about 40%. Students in Taiwan are intended to do more of observation and other type of tasks than students in Beijing do.

The result is shown in Figure 4 which indicates the percentage of each class of experiments with specific content representing what students are intended to do with objects and observables.

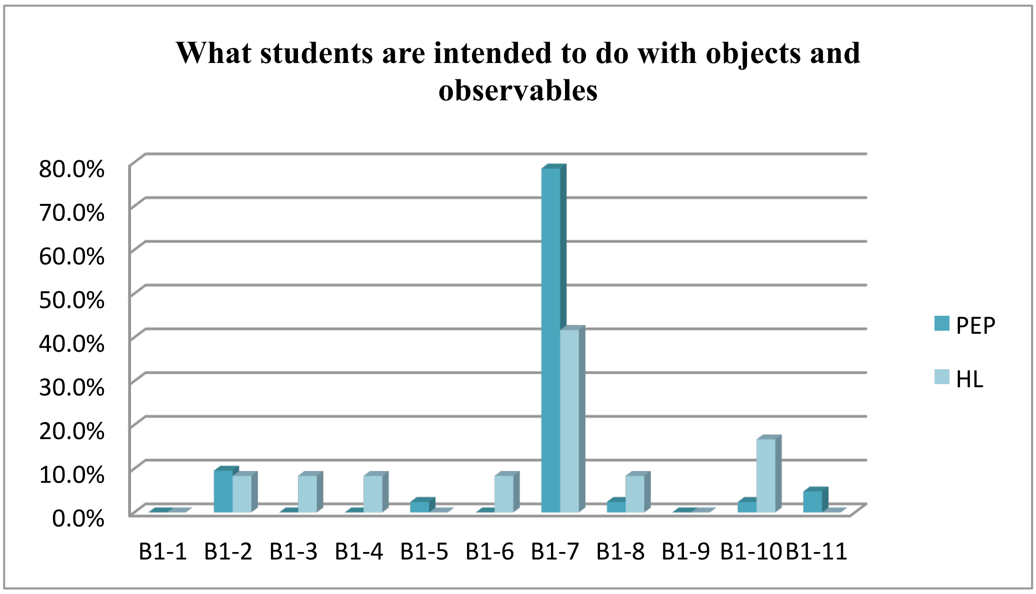

Figure 4. What students are intended to do with objects and observables inside laboratory (see Table 4 for the meaning of the categories)

Table 4. Categories of activities with objects and observables [14]
What students are intended to do B1

use	an observation or measuring instrument	B1-1
	a laboratory device or arrangement	B1-2
	a laboratory procedure	B1-3
Present or display	an object	B1-4
make	an object	B1-5
	a material	B1-6
	an event occur	B1-7
observe	an object	B1-8
	a material	B1-9
	an event	B1-10
	a quantity	B1-11

What students are intended to do with ideas (B2)

This sub-dimension of the map (B2) is related to what students are intended to do with ideas.

Labworks are not only the observation or operation of object, but also to allow students to practice their ideas, improve their knowledge structure and even inspire more inspiration through experiments. This means that labwork is ‘hands-on’ as well as ‘with the brain thinking’. Undoubtedly, labwork is the bridge connecting theory and practice, representation and concept. Therefore, a labwork task can also be classified according to what the students are intended to do with ideas. [3]

Some labwork tasks simply require direct reporting of observations, though the selection of features to observe and record is inevitably influenced by the teacher's and/ or student's purposes and understandings:

- report observation(s) (B2-1)

e.g. describe the shape of crystals of a given substance.

Other labwork tasks require the students to identify a pattern, or regularity, in the behavior of the objects or events observed:

- identify a pattern (B2-2)

e.g. Separation and purity of the mixture. After the labwork course of extraction, distillation, evaporation and recrystallization, students can select a method correctly when the mixture is needed to be separated according to the physical properties of the substance. [18]

One particular type of 'pattern' which is common (and so worth keeping as a separate category) is the relationship between experiment objects, or between physical quantities (variables). Students may be asked to:

- explore relations between experiment objects (B2-3)

e.g. Periodic trends: students will learn the periodic trends through observing the change of chemical reactions condition, when they make Na、Mg and Al react with water separately. [13]

- explore relation between physical quantities (B2-4)

e.g. explore the volume of 1mol material; [18]
through experiment, explore how much influence the volume, temperature and concentration of 1mol material have on the rate of chemical reactions.

- explore relations between objects and physical quantities (B2-5)

e.g. find out how catalyst affect chemical reaction rate; [13]
measure heat of solution, neutralizing heat, to explore relationship between chemical reaction and energy change; [13]
measure the voltage of chemical battery with different electrodes. [13]

Another type of labwork task is one which is designed to help students to develop their ideas by seeing that a new concept, or quantity, can help them to interpret their observations. However, this type of labwork task is not involved in textbooks both in Beijing and Taiwan. Another type of labwork task involves the testing of predications. A prediction may be simply a guess, or may be deduced from a more formal understanding of a situation, such as an empirical law, or a theory (or model). In labwork tasks of these sorts students are intended to:

- test a prediction based on a guess (B2-8)

e.g. The chemical property of CH_4、C_2H_4 [13]

(Students infer chemical properties of methane or ethylene through their life experiences and the observing of molecular structure of methane, ethylene observation.)

- test a prediction from a law (B2-9)

e.g. the reaction between Na_2O_2 and water, Na_2O_2 and CO_2 (PEP2) [13]

(Students' prior knowledge: Mastering the collection method and testing methods of hydrogen, oxygen、chemical property of base and Na_2CO_3; with the hint of labwork manual, students are intended to describe the phenomenon of the reaction between Na_2O_2 and water, test the products and write down the chemical equation; after that students need to design a method to test the product of the reaction between Na_2O_2 and CO_2).

Finally, some labwork tasks are about accounting for observations, either by relating them to a given explanation or by proposing an explanation. [3] An 'explanation' might be an empirical law, or a general theory, or a model derived from a general theory, or general principles derived from a theoretical framework. In some tasks, the explanatory ideas are known in advance and the student is expected to use these to account for what is observed, perhaps extending or modifying the framework of ideas.

A variant of this is where two (or more) possible explanations are proposed and the task is to decide which accounts better (or best) for the data. In other tasks, the observations come first, and the student is expected to select an explanation from his/her existing knowledge, or perhaps to extend this to develop an explanation.

- account for observations in terms of a given explanation (B2-11-14)

e.g. By observing ethanol oxidation reaction (combustion and catalytic oxidation), students are intended to have a deeper understanding of organic matter oxidation combined the definition of redox. [13]

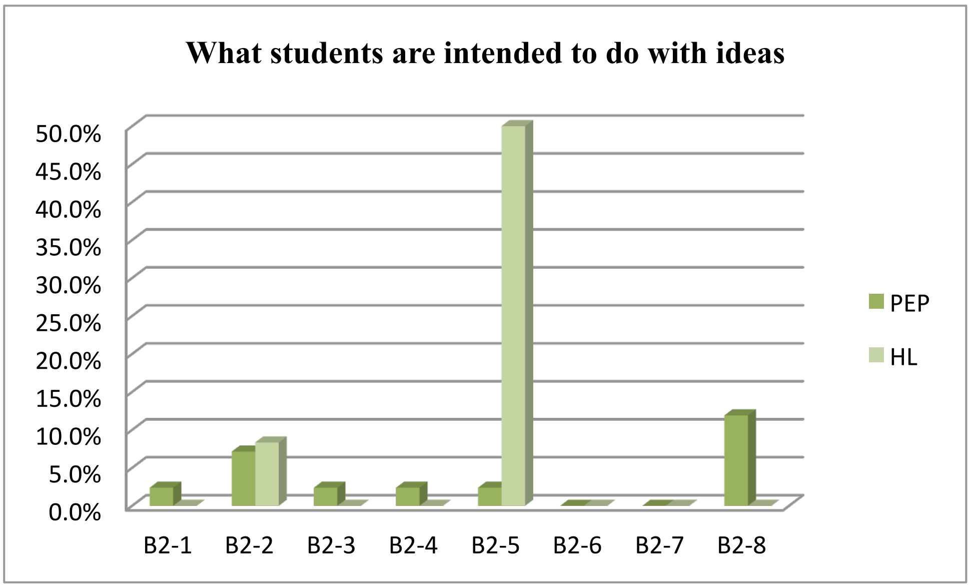

Figure 5. Aspects related to what students are intended to do with ideas.

As seen in Figure 5 and Figure 6, students both in Beijing and Taiwan are supposed to ‘accounting for observations in terms of a given law’. It is significant that students in Taiwan need to ‘explore relations between objects and physical quantities’, which takes the percentage of nearly 50%. In Beijing, however, students are required to ‘account for observations by proposing a law’, and ‘test a prediction from a law or from a guess’.

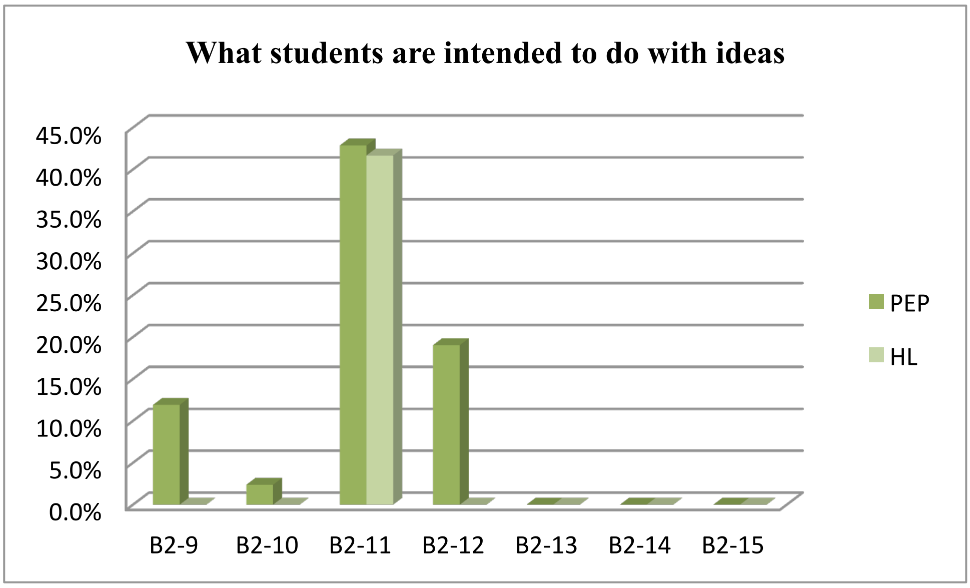

Figure 6. Aspects related to what students are intended to do with ideas. The categories are given in Table 5.

Table 5. Categories related to what students are intended to do with ideas [14]
What students are intended to do B2

direct reporting of observation (s)		B2-1
identify a pattern		B2-2
explore relation between	objects	B2-3
	physical quantities	B2-4
	objects and physical quantities	B2-5
'invent' a new concept (physical quantity, or entity)		B2-6
determine the value of a quantity which is not measured directly		B2-7
test a prediction	from a guess	B2-8
	from a law	B2-9
	from a theory	B2-10
account for observations	in terms of a given law	B2-11
	by proposing a law	B2-12
	in terms of a given theory	B2-13
	by proposing a theory	B2-14
choose between two (or more) explanations		B2-15

Take ‘chemical energy and heat’ for example, students in Beijing would make an interpretation according to the phenomenon of the change of reaction temperature, which is ‘accounting for observation by proposing a law’. The same experiment in Taiwan, however, requires students to prepare a specific solubility solution precisely following the procedure and record the temperature change with the reaction occurrence, which help students explore relations between objects and physical quantities.

The result is showed in Figure 5 and Figure 6 which indicate the percentage of each class of experiments with specific content representing what students are intended to do with ideas.

Observation or ideas driven (B3)

Most experiments read in chemistry textbooks published by PEP are object driven, which means ‘what the students are intended to do with ideas arises from what they are intended to do with objects’. On the contrary, most labworks showed in chemistry textbooks published by HL are ideas driven, which means ‘what the students are intended to do with objects arises from what they are intended to do with ideas’.

The result is shown in Figure 7 which indicates the percentage of each class of experiments with specific content representing whether an experiment is observation driven or ideas driven.

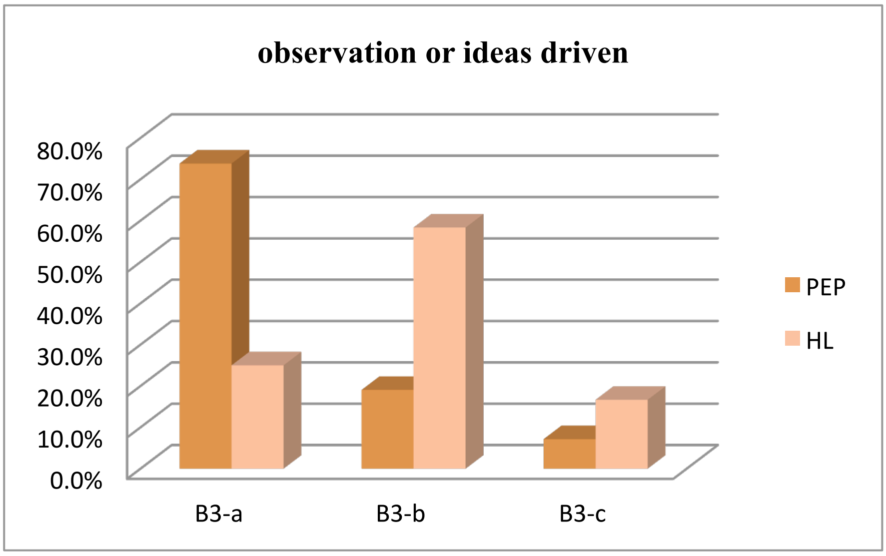

Figure 7. Students’ activities driven by observation or ideas (see Table 7 for the meaning of categories)

Table 6. Categories corresponding to students’ activities driven by observation or ideas [14]

B3-a	What the students are intended to do with ideas arises from what they are intended to do with objects
B3-b	What the students are intended to do with objects arises from what they are intended to do with ideas
B3-c	There is no clear relationship between what the students are intended to do with objects and with ideas

Degree of openness/closure (B4)

This categorization aims at showing how to take the initiative in labwork activity. Figure 8 and Figure 9 show the modules of laboratory manuals in Beijing and Taiwan separately. We can figure out students in Beijing have higher degree of participation in chemistry experimental courses, which means they could choose the apparatus and discuss the procedure with peers or teachers. Students in Taiwan, on the contrary, just need to follow the procedure rather than design the experiments. Students both in Beijing and Taiwan are required to record phenomenon and data of the experiments and finish the reports. We should notice that chemistry textbooks published by Hanlin Press in Taiwan emphasize more on waste disposal. Textbooks published by PEP in Beijing, however, pay more attention on applying the principle or reaction in our daily life.

Beijing

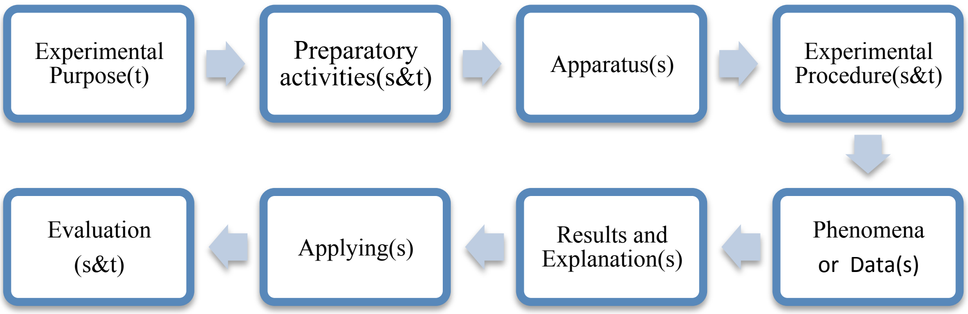

Figure 8. Modules of laboratory manuals by PEP in Beijing (see Table 7 for the meaning of abbreviation)

Taiwan

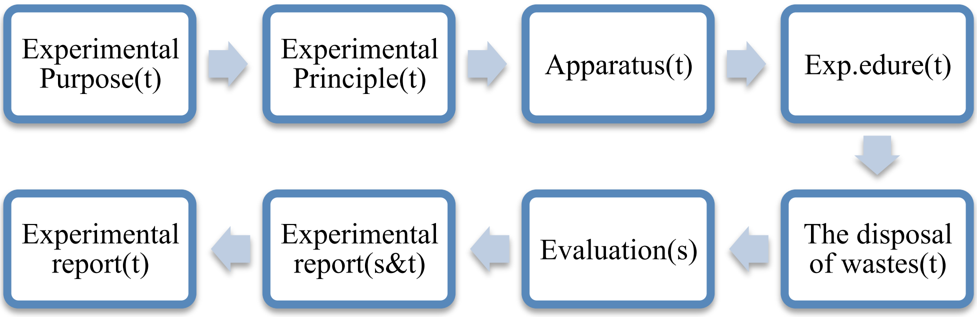

Figure 9. Modules of laboratory manuals by Hanlin Press in Taiwan (see Table 7 for the meaning of abbreviation)

Table 7. The meaning of abbreviation in Figure 8 and Figure 9

s = chosen by students
t = written in the textbook
s&t = decided through teacher- student discussion

Level of student involvement (B5)

This aspect deals with the level of student involvement: as observer, as assistant, or as executor of the task with other students or on one's own. According to chemistry curriculum standard developed by the Ministry of Education published by PEP in Beijing, there is not a clear boundary between students' experiments and demonstration experiments, which depends on the condition of the lab or the schedule. In Taiwan, however, there are 12 experiments, including 10 students' experiments, in which students act as executors of the task, and two demonstration experiments, in which students act as assistant or as observer.

Dimension C: Details of context

There are many factors that may affect the result of an experiment, such as whether students have enough time to complete the labwork; whether they can get help or discuss with someone when they have a problem during experiments; or if students have the opportunity to learn from the failure. Therefore, it is important to know some details about the context, and this dimension consists of the following four parts [14]:

- Duration: how much time is given to the task
- People whom students interact with: people whom students are expected to interact with in carrying out the task
- Information resources available to students: what information sources are available to the student to assist with the task
- Type of apparatus involved: what type of apparatus in carrying out the task

The information of the details of context is from the interviewing to chemistry teachers in Beijing and Taiwan.

Duration (C1)

In Beijing, each experiment is usually less than one class (40 minutes), but in Taiwan, each experiment lasts for one class (50 minutes). There is always a deeper discussion about the experiment in Taiwan in the next class, and teachers help students build the bridge between the theory and practice. In Beijing, however, students always get the conclusion or learn something new directly from the experiment, and teachers review the knowledge in the next class.

People whom students interact with (C2)

Students in Beijing prefer to discuss with their classmates carrying out the same labwork task, and when they fail to get a result and the phenomenon is different from what they expected before, they will ask the teachers for help. Similarly, students in Taiwan would like to interact with other students carrying out the same labwork task or students who have already completed the labwork task and teachers or more advanced students (demonstrators).

Information sources available to student (C3)

Both in Beijing and Taiwan, students get information source through textbooks, rather than computers or mobile phones in class.

Type of apparatus involved (C4)

In Taiwan, some teachers confirmed in answering a question that students use standard laboratory equipment, and some students are trained and volunteer to prepare the apparatus for experimental course. In Beijing, however, teachers will prepare the apparatus and students just do the experiments.

Comment

In Beijing, most experiments are designed to help students learn facts or the property of materials that are the important parts in chemistry learning, and in most cases, students are required to use data to support a conclusion. During the experimental course, students have to make chemical reactions occur, and then they usually need to get the conclusion by accounting for observations in terms of a given law or accounting for observations by proposing a law, and usually explore the idea according to the operations on objects. More importantly, students are involved in the design of the procedure, and they learn directly from labwork and try to explain some phenomena occurred in daily life. Students in Beijing learn the property of common material in life through chemistry labwork and gain the capability of explaining and analyzing what they observe. Almost every experiment class is of short duration, but the labwork has turned out to be an indispensable part of the chemistry teaching. Thus we can come to the conclusion that labwork in Beijing may improve students' science literacy [1] which consists of the following three parts:

- Demonstrating scientific competencies that include identifying scientific issues,
- Explaining phenomena scientifically,
- Drawing conclusions based on evidence.

Chemistry experimental class of high school in Taiwan is similar with that in Beijing, but there is a little difference. Students in Taiwan learn concepts through labwork and then apply these concepts to the chemical experiments. The purpose of the labwork is to help students use the data they obtained through the experiments to support the conclusion and use the laboratory instruments correctly or set up and use the apparatus in the laboratory. Also, some of the students are able to help teachers prepare the apparatus in advance for other students. Students also explore relations between objects and physical quantities in the experimental class. And what's more, students learn the principles ahead of the experiments, so what they need to do is to follow the procedure as criterion or recipe. Students in Taiwan pay more attention on concepts learning and calculation. When students meet troubles in experiments, they can discuss with other students and teachers, and when they fail in an experiment their teacher would give them a chance to redo it. Thus students in Taiwan have more chances to learn from failure in comparison with students in Beijing. From the chemistry textbooks published by Hanlin Press in Taiwan, we can see Taiwan's chemistry labwork teaching focuses more on helping students acquire scientific knowledge.

The chemistry education both in Beijing and Taiwan have managed to make students:

- Be interested in chemistry and be willing to make further explorations of the issues of utilization of natural resources, development of energy and environment protection;
- Come to know the role chemistry plays in daily life.
- Be able to discern which situation or issue in daily life is related to chemistry and science. [1]

Limitation:

This study is only involved in the teaching and learning of chemistry in high school in Beijing and Taiwan. Chemistry education in junior high school on both sides is not considered. There is a slight difference between Beijing and Taiwan in chemistry education in junior high school, which may have some influence on students' learning of chemistry in high school.

Due to various constraints, the study is mainly dependent on chemistry textbooks, chemistry laboratory manuals, interviews with teachers of high school and classroom observations. But the study may not be that perfect for lack of interviews with high school students both in Beijing and Taiwan.

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