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Blended learning activities in a chemistry experiment

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ABSTRACT: For experimental teaching, blended learning refers to learning in a real and virtual laboratory. The integration of a real experiment and a virtual experiment, to produce blended learning in a chemistry experiment course was explored. Based on a knowledge network diagram, the blended learning activities for a chemistry experiment course were designed covering theoretical knowledge, experimental skills and problem-solving. In this article, taking the *laboratory oxygen preparation by heating potassium chlorate and manganese dioxide* experiment as an example, the blended learning activities are presented and discussed.

INTRODUCTION

Blended learning is a currently active subject in the field of education technology. It advocates integrating face-to-face learning with on-line learning to achieve a complementary effect. The US Department of Education analysed relevant research between 1996 and 2008 and found that, compared with pure face-to-face learning or pure on-line learning, blended learning proved to be the most effective [1]. For experimental teaching, the blended learning refers to learning in both a real and a virtual laboratory. The virtual and real experiment complement each other and achieve a better effect. Integration is precisely what is advocated by blended learning.

KNOWLEDGE NETWORK DIAGRAMS

A knowledge network diagram reflects the knowledge points, as well as their mutual relationships, in an experiment. As the key to the design of learning activities, it presents a clear relationship among the knowledge points. Yang believes that knowledge modelling is a process of constituting a knowledge network diagram, starting from the inherent semantic relationships, which express the knowledge [2]. The knowledge network diagram reflects connections among knowledge points. However, these connections are not always a direct semantic relationship, but sometimes a subordinate relationship. The author analysed the knowledge content of types of experiments to constitute a knowledge network diagram. It presents the knowledge points of each experiment, as well as the affiliated relationships of knowledge points. This is illustrated by an experiment, *laboratory oxygen preparation*, see Figure 1.

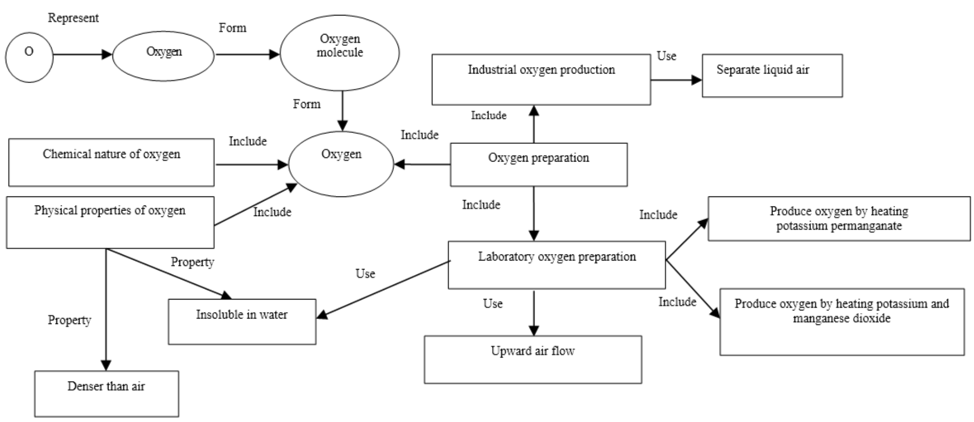

Figure 1: Knowledge network diagram for *laboratory oxygen preparation*.

To build a knowledge network diagram for the laboratory oxygen preparation experiment, first establish the subject *oxygen* and related knowledge points, then, categorise the knowledge points. Use different shapes for different types of knowledge point. In Figure 1, there are five parts, i.e. the oxygen's composition, chemical nature, physical property, industrial preparation and laboratory preparation. There are also specific knowledge points for each part.

Second, confirm the affiliate relationships of knowledge points (such as upper, parallel or lower relationship) and identify them by particular lines. For instance, there are two ways for the laboratory preparation of oxygen, namely water evacuation and upward air evacuation. For these two ways, the preconditions are, respectively, that oxygen is insoluble in water and that oxygen is denser than air, which are the physical properties of oxygen. This, then, associates the physical properties of oxygen with the preparation of oxygen in a laboratory. This is displayed in Figure 1. Before a teacher explains to students how to produce oxygen in a laboratory, he or she must help students to understand the physical properties of oxygen. Therefore, the knowledge network diagram helps in the arrangement of teaching activities, and also in the design of learning activities.

BLENDED LEARNING ACTIVITIES

In contrast to experimental teaching, blended learning activities are carried out in a real laboratory and a virtual laboratory. To categorise these learning activities, the problem and project-based learning activities are often divided into three types, i.e. exploration, illustration and reflection [3].

Some Chinese scholars, e.g. Wu analysed learners' behaviour in an on-line learning environment and classified them into three types; namely, knowledge acquisition, problem-solving and tactics [4]. Yang categorised learning activities from various perspectives: internal and external activities from the perspective of inside or outside a learner; individual learning, group communication and self-management from the perspective of the individual or group; meaning construction and ability-developing activities from the perspective of inner connections between activities and learning objectives [2]. Li et al sort learning activities into classroom learning and on-line learning activities, according to the learning environment [5].

These scholars categorise learning activities from different angles, but the question arises of how to classify experimental learning activities. Based on studies mentioned above, the author has categorised experimental learning activities in a blended learning environment into four types, according to the type of experiment and experimental objectives: activities for theoretical knowledge, activities for experimental skills, activities for problem-solving, and activities for evaluation and reflection.

The progress of each experimental stage depends on the learning activities. Both real experiments and virtual experiments have their advantages and disadvantages. On the basis of affiliate relationships of different knowledge displayed in the knowledge network diagram, the author designed learning activities for each experimental stage. For example, the activities for theoretical knowledge mainly support the preview stage of the experiment; the activities for experimental skills for the operation stage; the activities for problem-solving for the consolidation and improvement stage; and the activities for evaluation and reflection for training students' ability to evaluate and reflect. Various learning activities constitute a sequence of activities that affect and connect with each other. Each type of learning activity is now considered.

Activities for Theoretical Knowledge

In this article, theoretical knowledge refers to factual and conceptual knowledge. Factual knowledge needs to be memorised, while conceptual knowledge needs to be memorised, applied and discovered through experiments. As for the experimental teaching of chemistry in middle school, the theoretical knowledge chiefly refers to experimental principles, experimental objectives, experimental instruments and features of chemicals. Because this kind of knowledge is acquired at the preview stage, students often do not pay it sufficient attention. Therefore, in order to help students memorise and use this factual and conceptual knowledge, knowledge cards were designed and there were arranged in the virtual laboratory some brainstorming, conceptual conflicts, preview reports and other activities.

The knowledge cards are designed with both pictures and words. The front side covers the experiment-related knowledge points, accompanied with pictures, while the reverse side covers the experiment-related problems and precautions. This particular design can vividly present students with experimental principles, experimental objectives, experimental instruments and chemical knowledge.

When designing the brainstorming activities, the author mainly takes two aspects into consideration, i.e. the difficulty of the question and the environment for the activity. If the question is quite difficult, it will not be easy to motivate students to participate in discussion. In addition, no matter whether it happens in a real laboratory or a virtual laboratory, teachers should ensure a comfortable environment for students.

For example, in Figure 1, the module *the chemical nature of oxygen* is appropriate for a brainstorming activity, which can be carried out in a face-to-face manner or in the on-line forum of a virtual laboratory. If the class size is too large, it is better to divide the class into several groups to conduct the brainstorming session and appoint one representative of each group to report their results.

The *conceptual conflict* requires students to explain a contradiction, which will help to stimulate students' cognitive understanding. Because students' original cognitive structure had not assimilated the new knowledge, they have to reorganise and update their cognitive structure. Conceptual conflict will motivate students to rebuild the knowledge structures.

In order to design these types of activity, teachers should be familiar with students' original cognitive structure, and the differences and connections between the new knowledge and students' original knowledge. For example, for the *physical properties of oxygen*, the question can be posed …*must the colourless, odourless and insoluble gas be oxygen?*

Teachers can design an activity discussing the relationship of *colourless*, *odourless and insoluble gas*, and *oxygen*, causing a conceptual conflict, and inspiring students to think about the characteristics of other gases and, then, to judge the differences and similarities between other gases and oxygen.

The *preview report* is designed to evaluate students' preview results, i.e. whether students previewed the experiment or not, the preview outcome and problems with the preview. Teachers and students should jointly participate in these activities. Once students finish the preview stage, they must fill out the preview report. Teachers should examine these reports and give timely feedback to students.

Activities for Experimental Skills

The Chinese Ministry of Education, Chemistry Curriculum Standard, or just the *Standard*, points out that …*chemical experiments are important ways to conduct scientific research. Basic experimental skills are the foundation and the guarantee for students learning chemistry and engaging in exploration activities*. The Standard lists specific requirements, viz. how to separate mixtures and produce gases; how to make chemicals; how to heat, choose, and connect instruments; how to mix solutions; how to verify materials; how to use chemical language to record an experiment; and how to complete simple calculations [6].

To help students to acquire basic experimental skills, the author designed such activities as *watch on-line video*, *explain demonstrated experiment*, *conduct virtual experiment*, *conduct real experiment*, *improve the experiment*, *fill in and review the experimental report*. For these activities, only the *conduct real experiment* happens in a real laboratory; the others are in a virtual laboratory.

There are two ways to produce on-line videos. The first is to download the experimental videos from the Internet and modify them. The second is to invite chemistry teachers to demonstrate the experiment and film the demonstration, adding necessary narrative and subtitles and, then, cutting them down into a series of four-minute videos. A four-minute video is a suitable length to maintain students' attention. Also, students are expected to answer questions while watching the video, e.g. *What are the typical phenomena in the experiment? Describe the procedures of the experiment briefly*.

Watching on-line videos can help students to visually familiarise themselves with the actual experimental instruments, and also produces a sense of reality, even in a virtual laboratory. For the *explain and demonstrate experiment* activity, it is the teacher who explains to students the experimental objectives, experimental principles and the difficulties. Points that confuse students are considered at the preview stage.

The virtual experiment is conducted after the students' previews and the teacher's demonstration. At that time, students already know the basic experimental principles. The virtual experiment offers a scenario for students' practice before conducting the real experiment. In this way, students can familiarise themselves with the experimental principles and phenomena, and use of the experimental instruments, which will reduce errors in a real experiment.

In the after-school review, students may feel confused about the utility of chemical instruments or the experimental phenomenon. Normally, it is impossible for students to do the experiment again due to limits on time, place and chemicals. However, the virtual experiment allows the sharing of digital resources.

Students can learn by themselves or review the experiment anytime and anywhere. To enable students to apply theoretical knowledge to the experiment, and train them to observe and run the experiment, the virtual experiment emphasises several key points, such as select chemical instruments, check air tightness, choose the approach to the experiment, organise chemical instruments, observe and record the experimental phenomena, and write down chemical formulae.

In order to prevent students copying results or even downloading the results from the Internet, the author adds a monitoring and time limit function to the activity, filming the students conducting the virtual experiment. When evaluating a student's performance, the teacher can randomly examine the video of the student doing the experiment. The student would be warned if he or she copied the experimental results or conducted the experiment carelessly. The time limit function is mainly for specific experimental procedures, such as the organisation of chemical instruments. If a student fails to complete the process in time, his or her score will be counted as zero.

The *conduct real experiment* activity happens in a real laboratory. A virtual experiment is not a replacement for a real experiment because the former does not require the student to operate the actual experiment. Therefore, to design this activity, the rules are different from those in a virtual laboratory. Here, students identify the differences and similarities between a virtual experiment and a real one, find out whether the problems unsettled in a virtual experiment could be solved in a real experiment and understand the problems in a real experiment. For this activity, a group of two students is appropriate. If a group is large, some students may have to stand by instead of directly operating the experiment.

When students are confronted by problems in an experiment, the teacher or experiment instructor should offer necessary guidance to help them to analyse the reasons for the problem and inspire students to come up with a solution, rather than directly pointing out the reasons for a problems. This provides a good opportunity to cultivate students' innovative thinking and scientific exploration.

The *improve the experiment* activity aims to develop a student's ability in scientific exploration. After the experiment, students should think about a series of issues; for example, were there problems with the experimental device; whether it can be improved or not; why improve the device in this way. Students may design the improvement and apply it. A five-student group would be appropriate for this task. Each group should first discuss the problems of the device, design an improvement programme, and analyse the feasibility and risks of the programme. If necessary, they can ask for the teacher's help. If possible, the teacher should examine the design programmes of all groups and present suggestions.

For the *fill-in and review the experimental report* activity, students should complete the experimental reports independently after finishing the virtual experiment. The teacher will evaluate these reports. After that, students should improve their reports, according to the teacher's evaluation. As for how to design and evaluate the experimental reports, the author has discussed this in other articles [7][8].

Activities for Problem-Solving

The problem-solving activity is designed to train students to use chemical knowledge and scientific methods to analyse and solve simple problems. The teacher should design questions that integrate experimental tasks into daily life. By this means, students can understand the importance of chemistry and the close connection between chemistry and daily life, based on their personal life experiences. For example, in order to help students to understand the nature of oxygen and carbon dioxide, the teacher can design a scenario, such as *…there is a plastic bag full of gases in the market. What kind of gas is in the plastic bag?* The teacher can ask students to give their answers and explain the reasons, then, verify their answers. This connects the chemistry to students' daily lives, triggering their interest in chemistry. The author has designed some activities for problem-solving, such as *research experiments*, *chemistry in life*, *discovery by chemists*.

The purpose of *research experiments* and *chemistry in life* is to connect previous chemical experiments conducted by students to their daily lives. For example, the teacher could design activities, such as *collect documents about economic losses caused by iron corrosion*, *design an experiment to explore the conditions for iron corrosion*, *discuss methods to prevent iron corrosion*.

Another example is to *design a learning activity to understand the nature of sodium carbonate, commonly known as soda, and sodium bicarbonate, commonly known as baking soda, which are usually used for food or medicine*, *design an experiment to explore the nature of sodium carbonate and sodium bicarbonate*. A five-student group would be appropriate for this task. The marking scheme should be distributed before assigning the task to groups. This helps students to understand the specific evaluation points, but also provides guidance for exploration. This activity may include *present the problem*, *conjecture and assumptions, make up plans, conduct the experiment, collect proof, explanation and conclusions, reflection and evaluation,* as well as *communication*.

The activity, *discovery by chemists,* is to describe the process of chemists' exploration and discovery by presenting videos, animations, images, and text, of how chemists work. Students come to understand that chemistry is hard, rigorous work. Students watch the material and, then, answer questions. The teacher can post the answers on the forum.

For the *write a story about fun chemistry* activity, students are expected to write a fun story about chemistry based on their chemical knowledge from experiments. For example, for *the nature of oxygen*, students can write a story about *amazing oxygen* or *an oxygen's statement*, drawing on the chemical nature and physical properties of oxygen. Before the implementation of the activity, the teacher should create an activity zone in the forum, with the title, *write a fun chemical story about oxygen*, and list the specific objectives, time limit and suggestions. The story should reflect scientific principles, so that the story properly reflects correct chemical knowledge. Length should be 300 words and students can share their stories in the activity zone.

Activities for Evaluation and Reflection

From the preview to the consolidation and improvement, evaluation runs through the whole process of the experiment:

- At the preview stage, the author uses the evaluation scale and preview reports to evaluate the previews. In order to prevent students from copying, the author adds monitoring and time limits. By filming the experimental process, the teacher can evaluate performance.
- At the consolidation and improvement stage, the teacher can evaluate students' performances according to their chemical exploration programmes and papers.
- At the evaluation and reflection stage, the teacher will evaluate students' general performances during the whole experimental process, through students' conceptual diagrams, experimental assignments, digital files and on-line forums.

The virtual experiment and experimental report can be used to trace a student's experimental process and record the experimental phenomena. If a student chooses the wrong chemicals or organises devices incorrectly or writes chemical formulae with errors, the system will immediately warn the student and remind them to conduct the experiment correctly.

The evaluation function of the experimental report focuses on two aspects. First, it automatically records the experimental phenomena and data when a student conducts a virtual experiment. These phenomena and data are saved in the experimental report, which the student cannot change. This, to a degree, eliminates plagiarism. Second, it filters the answers of subjective questions in the experimental reports. If the similarity of answers in two experimental reports is greater than 60 per cent, both reports will be regarded as invalid. Then, the students must complete their experimental reports independently.

Additional Miscellaneous Activities

For third-year students in middle school, chemistry is a new discipline, which also includes new concepts, symbols and terms. Many students find it difficult to understand the new chemical concepts, summarise key points or apply them to daily life. In order to address these problems, the author has designed an activity to produce a *conceptual diagram*.

A conceptual diagram can well display the connections between concepts and help students to sort out the links between old and new knowledge. It can be used for a preview, as well as an after-school summary [9]. Students can draw the conceptual diagram by hand or produce it using software, such as Microsoft Word or Inspiration, from Inspiration Software, Inc.

For the experimental teaching of chemistry in middle school, hand-drawing is more feasible considering the limit of teaching time and the pressures of tests. Before producing the conceptual diagram, the teacher should set evaluation standards for the activity. For example, they should make sure there are meaningful connections between different concepts, the concept at the highest level should be divided into several lower level concepts, and that the association and integration of concepts are effective, meaningful and significant [10].

The on-line test includes single-choice and multiple-choice questions, short answer questions and design assignments. These questions cover all knowledge points of chemistry in middle school, forming a relatively complete test database. Each test is randomly generated, which means students do not take the same on-line test. There is a time limit for each test, according to the level of difficulty.

Once students complete an experiment, they must log in to the virtual laboratory and take the on-line test, finishing the test within a set time. All students' reflection reports, experimental programmes, typical work, teacher and students' evaluations, and study plans are filed. By analysing these on-line files, the teacher can identify problems in the experimental teaching and give students feedback. Meanwhile, students can reflect on their shortcomings and learn from others through self- and mutual evaluations.

BLENDED LEARNING ACTIVITIES FOR *LABORATORY OXYGEN PREPARATION*: AN EXAMPLE

There are several ways to produce oxygen in a laboratory. The production methods may involve the use of four chemicals, i.e. potassium permanganate, potassium chlorate, manganese dioxide and hydrogen peroxide solution. In this experiment, oxygen is produced by heating potassium chlorate and manganese dioxide, and collecting the oxygen. These two chemicals were chosen because they generally reflect the process of laboratory oxygen preparation. In addition, this method helps students to understand the meaning of a decomposition reaction. It also helps students to verify the nature of a catalyst through experiments.

Design of the various activities and related precautions already have been discussed. The *laboratory oxygen preparation by heating potassium chlorate and manganese dioxide* is taken as an example, to describe the design of blended learning activities.

Based on the learning objectives, the knowledge network diagram was first established and the knowledge was divided into different modules. The blended learning activities for the experimental process were designed, with the support of virtual and real laboratories. This produced the learning objectives, knowledge modules, tasks and forms of activities, time allocation, and learning outcome; see Table 1.

Table 1: Blended learning activities for *laboratory oxygen preparation by heating potassium chlorate and manganese dioxide*.

Experimental procedures	Learning objectives	Knowledge modules	Tasks	Form and time
Preview	1. Describe the nature of oxygen 2. Describe the experimental principles and objectives 1. Choose the method for laboratory oxygen preparation	See Figure 2	A1. Explain the content of the knowledge cards A2. Draw a diagram displaying the nature of oxygen A3. Complete the preview report on time	Knowledge cards (each group with three students, 10 minutes) Brainstorming (each group with five students, 8 minutes) Preview report (independently, 10 minutes)
Operation	1. Select experimental device and chemicals 2. Examine the air tightness of the device 3. Equip the experimental device 4. Observe and record the experimental phenomena	See Figure 3	B1. Watch the video about oxygen and answer questions B2. Listen to teacher's explanation of the experiment B3. Complete the virtual and real experiment B4. Fill in and reflect on the experimental reports	Watch on-line videos (5 minutes) Complete the virtual experiment (20 minutes) Complete the real experiment (35 minutes) Experimental report (5 minutes)
Consolidation and improvement	1. Verify the nature of the catalyst through the experiment 2. Solve daily problems about oxygen 3. Try to get oxygen by other means		C1. Watch the video about oxygen and answer questions C2. Listen to teacher's explanation of experiment C3. Complete the virtual and real experiment C4. Fill in and reflect on the experimental reports	Exploration experiment (each group with five students, 35 minutes) Fun chemical experiment at home (independently, after-school)
Evaluation and reflection	1. Be active in discussion and accept suggestions 2. Evaluate self and others' performances in the experiment 3. Reflect on self and partners' shortcomings, and propose suggestions for improvement		D1. Draw a conceptual diagram of laboratory oxygen preparation (independently, 10 minutes) D2. Keep a diary of experiment reflections. (independently, after-school) D3. Take the on-line test D4. File all records in one portfolio	

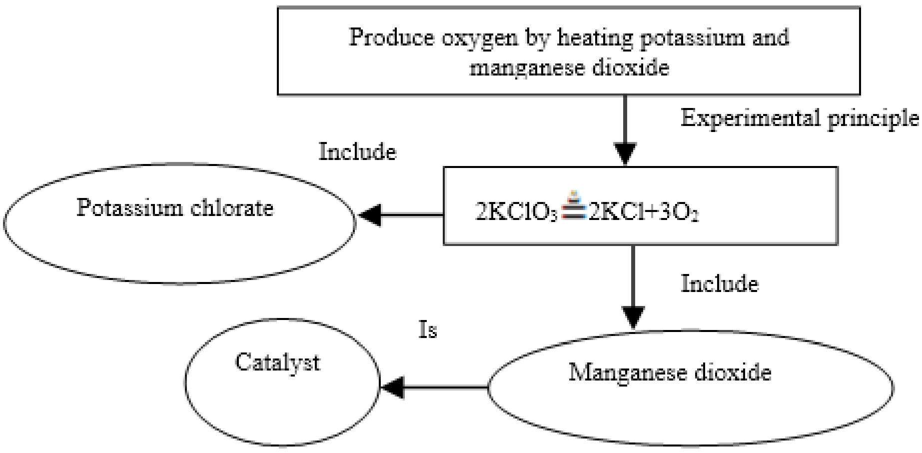

Figure 2: Preview knowledge modules.

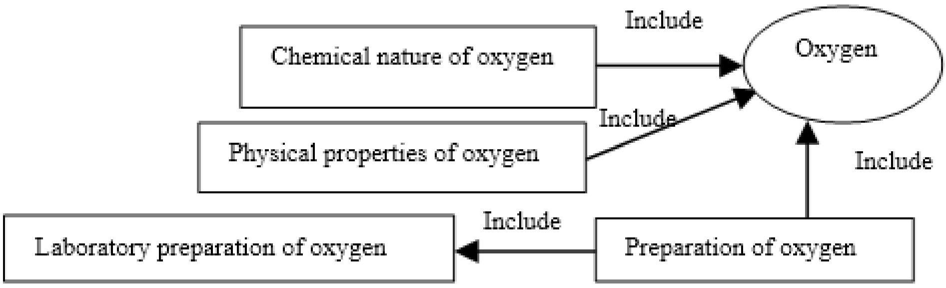

Figure 3: Operation knowledge modules.

CONCLUSIONS

With the implementation of the Chinese Ministry of Education *One-Decade Development Plan for Education Informatisation (2011-2020)*, the information technology infrastructure for education has been improved further. This offers favourable conditions for blended learning, which has become a trend in learning [11].

In this research, the author takes experimental teaching in middle school as an example of the design of blended learning activities in a virtual and real laboratory. Due to a lack of information technology and limited time and resources, blended learning in practice has suffered from a series of problems. This deserves further in-depth research on how to solve existing problems; how to apply blended learning to other disciplines; how to design the environment and resources for blended learning; and how to improve the effectiveness of blended learning.

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