

Applying contemporary education strategies to motivate students' interests in studying *Physical Chemistry* and to develop lifelong learning skills

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Abstract

In this paper several approaches such as demonstration, case study and problem-based learning have been introduced aimed at increasing the students' interests in learning *Physical Chemistry*. A useful method, concept mapping, has been given for assessment, particularly for the development of the students' self-directed learning skill and lifelong learning skill.

Introduction

First, *Physical Chemistry* is a theoretical chemistry course, which establishes and develops the subject in terms of the underlying concepts of physics and the language of mathematics. Most students believe it is the most difficult course in the School of Chemistry, because it consists of lots of complicated mathematical calculations and has an extensive theoretical base, which is generally a negative point for today's students. It can turn students off quickly unless they see the value in it.

Second, teacher-centred teaching strategies are still being used at most universities in China which means the teacher gives lectures and the student takes notes in the classroom and memorises them, then pours it out during the final examination. During this teaching process students can not develop any skills except memory. The students are in the surface level of learning process and their aims are passing the examination. They can get high marks in the final examination but they will forget the knowledge quickly after examination and they may think: Why do I need to learn it? Are there any benefits for me to learn it? And if they cannot find the correct answer they lose their interest in learning and feel it is boring.

Students are on the rapid explosion of knowledge. According to reports [1] there are 1.2 million volumes of documents published every year in the world and 350,000 documents produced per day on average. Figure 1 shows the changes within the 20th century. At the same time the average lifespan of document has become shorter than before — about five to seven years. This means it is impossible for teachers to teach the students in a four-year period what they will need during their whole life. In addition, the increasing technology and social complexity leads to the rapid development of the integration of inter-disciplinary knowledge, many students leaving university and entering a range of jobs in society are not necessarily best prepared by studying a single science subject. Most of the problems faced by professionals in the course of their work are interdisciplinary in nature and require the experience of a multi-skilled team to solve. So it is important to motivate the students' interest in learning and to develop their self-directed learning skills and communication skills.

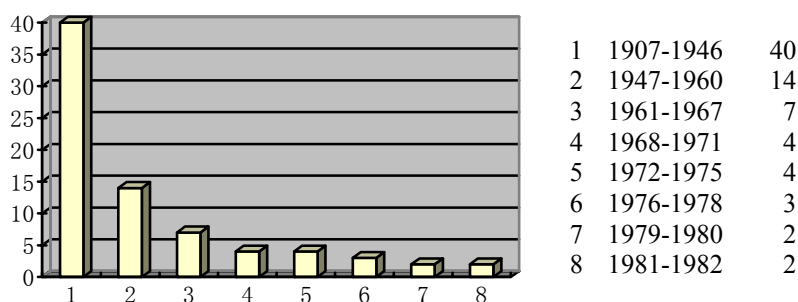


Figure 1. The number of years needed to produce a million documents for periods within the 20th century

Last, according to a survey [2] of the 200 leading companies in Europe who employ science graduates; they needed graduates with oral communication skills, written communication skills, teamwork skills, self motivation to succeed, group leadership skills, enthusiasm for a task, initiative and creativity, problem solving skills, etc.

All in all, the strategies that we have used in teaching and learning can not meet the social needs and the student needs for their future life. Therefore it is important for teachers not only to teach the students knowledge but also to develop their interest, skills for learning and problem solving. The teacher must move from teacher-centred to student-centred strategies. This paper introduces several methods to motivate the students' interest in learning *Physical Chemistry* and foster the development of lifelong learning skills.

Teaching strategies to enhance the students' interest in learning

Demonstrations

According to Lagowski [3] students retain 10% of what they read, 26% of what they hear, 30% of what they see, 50% of what they see and hear, 70% of what they say, and 90% of something they say as they do something. So if the teacher shows as many demonstrations as they can to the student as well as letting the student do demonstrations by themselves, the student will learn more actively and effectively. For instance, when teaching the Law of Gay-Lussac, the teacher can use the liquid nitrogen to decrease the temperature of the atmosphere inside the balloon and show the balloon's volume changing at the constant pressure.

Historical story

The development of science and technology can not be separated from the contributions of scientists. The science stories will inspire students to overcome the difficulties and to gain success. So giving the relevant story will spark the students' inner-motivation. Only with inner-motivation will the students show their initiative and creative abilities in their learning and working processes.

Multimedia technology

With the development of computer technology multimedia methods are being increasingly used in teaching practice. A multimedia course can combine sound and pictures with knowledge. This reinforces the fact that students retain 50% of what they see and hear, as the use of multimedia technology gives students more information than just writing on the blackboard, and increase the chance of active learning. But on the other hand it can also make a more boring lecture for the students, if too much useless information is given or if, when using the projector, the light in the classroom is too dim. To avoid these disadvantages the teacher can combine it with other strategies and give students more opportunity to think and ask questions.

Case study

Chemistry is a science that is very relevant to our real life. It would be worthwhile to find some real cases before the teacher gives a lecture. When students find that what they will learn is useful to the society, they will be active learners. Case studies are capable of being delivered with a range of styles, they can be designed to complement (not replace) other teaching approaches, and focus on re-visiting topics rather than attempting to cover an entire syllabus. In addition, the contexts and delivery styles can be selected in order to be stimulating. As an example, after lectures on chemical equilibrium, the teacher can present the following real case.

In the early 19th Century people wanted to obtain diamond from graphite. Diamond is expensive because of its properties of hardness, rigidity and the reflection of beautiful colours while graphite is very cheap. But they did not know how to transform graphite into diamond. The teacher then asks the students how they might solve this real life problem with a knowledge of free-energy function (Hermann von Helmholtz introduced Helmholtz free energy in 1882, and Willard Gibbs introduced Gibbs free energy in 1876) and equilibrium constant. From this case the students will learn how to use thermodynamic data to predict the possibility of one reaction and control it by altering conditions such as temperature, and pressure.

Problem-based learning

Problem-based learning is a pedagogical approach based on recent advances in cognitive science research on human learning [4]. PBL has been widely used in undergraduate settings in Western countries but there is very little published on the application of PBL in science education in China. A PBL class is organised around collaborative problem solving activities that provide a context for learning and discovery. The responsibility for learning is with the student; not with the facilitator. There are five well-defined stages in the PBL process: introduction, inquiry, self-directed study, revisiting the hypotheses, and self-evaluation [5].

In the introduction stage, students are presented with a succinct statement of the problem that gives them a well-defined role that they can adopt. In the next stage, inquiry, the facilitator guides the inquiry process so that students elicit data about the problem, look for additional information in the materials provided, and write down the topics that they need to look up. The facilitator demonstrates how to organise the problem solving process by breaking it up into distinct steps. The information generated in this process is entered in one of three categories: facts, hypotheses, and learning issues. At the end of the first section, students commit to one of the many hypotheses and select learning issues that they will pursue independently. Having committed to a hypothesis and chosen learning issues, students look up information from different sources with some initial guidance in the self-directed study stage. After their self-directed study, students evaluate the resources they used and share information with their colleagues during the revisiting of the hypothesis stage (from this stage they can be trained in both teamwork skills and communication skills). They reconsider their

hypotheses with the benefit of the new information they have gathered while trying to solve the problem. Finally, during the self-evaluation stage, students are asked to evaluate their efforts and those of their team mates' as problem solvers, as self-directed learners, and as members of a group and to discuss these evaluations with their group. During all these stages, the instructor facilitates the process by listening to the group's discussion and probing their understanding, interceding appropriately when they proceed to apply their science knowledge [6, 7] and to model the problem solving process.

For example, the facilitator first gives an introduction to the students: when you visited your cousin who lived beside a small branch of Yangtze River you found that there were dead fish in the river. You want to solve this problem and protect the environment.

The facilitator guides the inquiry process by:

- advising the students to investigate the surroundings of the river (they might find that there is a factory upstream that releases phenol into the river);
- guiding the students to develop hypotheses on how to reduce the pollutant (electrochemistry oxidation method or photo catalysis oxidation method can be used to reduce the content of phenol); and
- dividing students into two groups according to the learning issues and let them find information and learn by themselves using the Internet, library CD-ROMs, textbooks, and other faculty.

After self-directed learning, the students would be required to discuss the problem in groups. This provides both a means of communication and a way of oral presentation. Then the students revisited their hypotheses and compared the advantages and the disadvantages of the two methods. At the same time, the tutor must inform the student that it does not mean that this problem can only be resolved by the two methods indicated, and that the reason for choosing them is to focus on *Physical Chemistry* learning issues. At a final stage of self-evaluation, the students can become aware of themselves and how to improve their own self-directed learning.

Concept mapping to assess the results of learning

Assessment is an important aspect both for teaching and learning. For learning it can make students have a deep understanding of how much and how well they have learned. For teaching, it can allow teachers to improve their level of teaching. When one subject is finished, teachers must assess the level of student learning. Examinations are the most widely used method. However they can not reflect all the problems and may not show the abilities that the students have gained. Furthermore, students do not like examinations and if their mark is low it may reduce their confidence to continue learning. It is preferable to find other methods to supplement examinations. Concept mapping is an alternative method: it can show the teacher how much the students knew and how much they didn't know; and the students can assess their own learning.

Furthermore, the purpose of university assessment is two fold: firstly, the role that we are most familiar with, certification. Secondly, for training students to be lifelong learners and lifelong assessors of their own learning, which perhaps is the role we do least well. But for science graduates to become lifelong learners they need to be able and prepared to understand assessment of the learning tasks they face throughout their lives. This means that assessment has to move from the exclusive domain of assessors into the hands of the learners. Therefore assessment needs to be seen as an important skill in lifelong learning. In order to develop the student's skill of assessment, concept mappings can be used.

Concept mapping was developed by Professor Joseph D. Novak at Cornell University in the 1960s. The concept map is a knowledge representation tool in the form of a graph comprised of boxes connected with labelled arcs. Words or phrases that denote concepts are put inside the boxes, and relationships between different concepts are specified on each arc. Propositions (node – link – node triads) are a unique feature of concept maps, compared to other similar graphs. Propositions consist of two or more concept labels connected by a linking relationship that forms a semantic unit [8]. Concepts are defined as 'perceived regularities in events or objects, or records of events or objects, designated by a label' [9]. 'A significant variation of a proposition is a crosslink, which shows the relationships between ideas in different segments of the map. To see a relationship between two different concepts is associated with insight. Links specify the relationship between concepts by words or signs/symbols. Arrows are used to designate the directionality of the relationship; if an arrow is not used, it is assumed that the direction of the relationship is downward.' [10]

Concept mapping is quite suitable for complicated theories. *Physical Chemistry* is just such a theory that contain many equations and theories. Even after the learning process the students usually are not exactly aware of what they have learnt and what are the relationships among the theories. Through the drawing of concept maps students will become aware of what they have learned and what they need to learn, and develop their self-directed learning and lifelong learning skills. Concept mapping can be used in different ways according to differing objectives: formative assessment and summative assessment. Formative assessment is ongoing and is designed to inform learners on what it is they do and do not understand. It happens during learning and not at the end of it, as opposed to summative assessment.

For instance, when giving lectures on electrochemical cells, teachers can give a finished concept map as shown in Figure 2 as a formative assessment. In the teaching/learning process, the tutors are able to tell the students what they are learning and what they will learn and what the relationships between the different concepts are. On the other hand Figure 2 can also be used as a summative assessment. For this purpose teachers can give an unfinished concept mapping, for example the rectangles can be unfilled and students are required to fill them in. Using this method the teacher will know what the student has

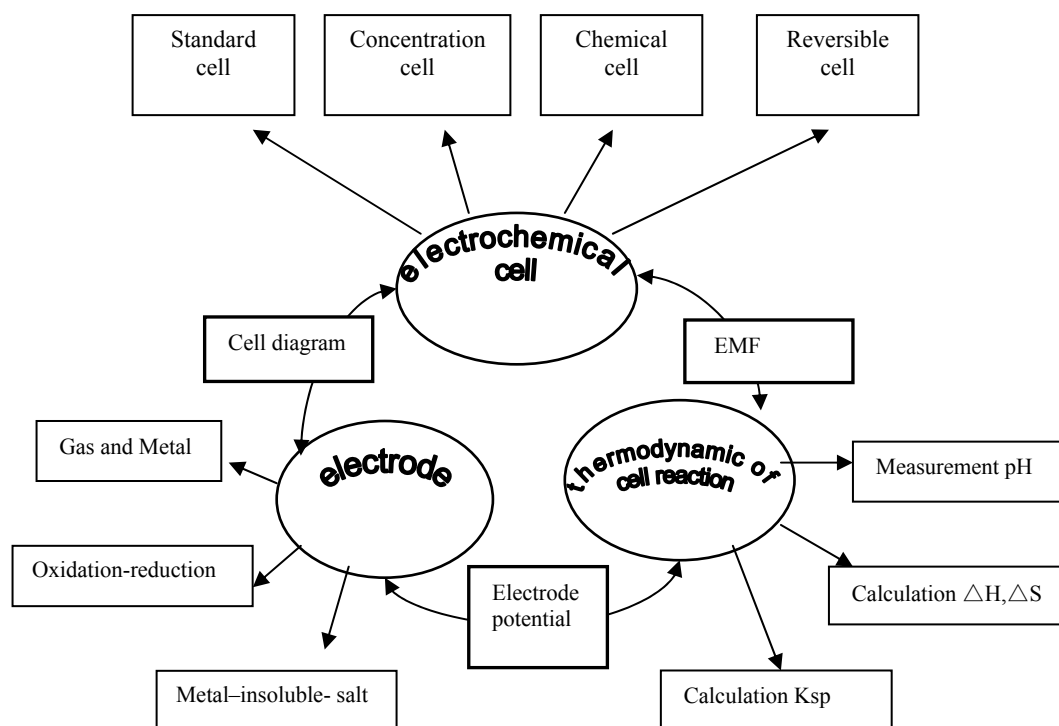


Figure 2. Concept map of electrochemical cell

grasped and where they need more explanations. The student will also know about it and they can put more efforts into what they did not know. By using this approach the student will develop their self-directed learning skill and lifelong learning skill.

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