Application of modern teaching strategies in physics teaching

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Abstract

Contemporary society requires learners to develop abilities and skills besides having a basic knowledge of a discipline. In this paper, some modifications and improvements of teaching approaches in the courses of *Modern Physics* and *General Experimental Physics* are suggested by using the contemporary teaching strategies of problem based learning and concept mapping.

Introduction

In today's world, because knowledge and technology becomes outdated rapidly and is updated constantly, much of what students will need to know in their future career after graduation has not yet been generated! This knowledge explosion cannot be solved by adding more courses. Therefore, the responsibility of teachers in university or college is not only to teach the students with the particular or professional knowledge of their discipline but also to help them develop successful lifelong learning skills.

In order to improve university teaching methods, research into science teaching and learning has been done in western universities for over twenty years. As a visiting scholar at The University of Sydney, I have learnt a great deal about modern teaching theories in western universities. In this paper, I will briefly introduce a number of contemporary teaching approaches; discuss the teaching approach used at Tsinghua University; and based on what I have learnt at The University of Sydney, make some suggestions for the modifications to my teaching approach.

Contemporary teaching approaches – problem based learning and concept mapping

Figure 1 shows the skills that are used frequently by physics graduates in selected typical employment: industry; government laboratories; and high school teaching. It is surprising the problem solving skills and interpersonal skill are more often used in these three careers than a knowledge of physics. This result does not imply that the knowledge of physics is no longer important, but indicates that the other skills are as important as the knowledge of physics. Therefore, it is the responsibility of universities to encourage students to develop these skills as well as gain an understanding of the knowledge of the discipline.

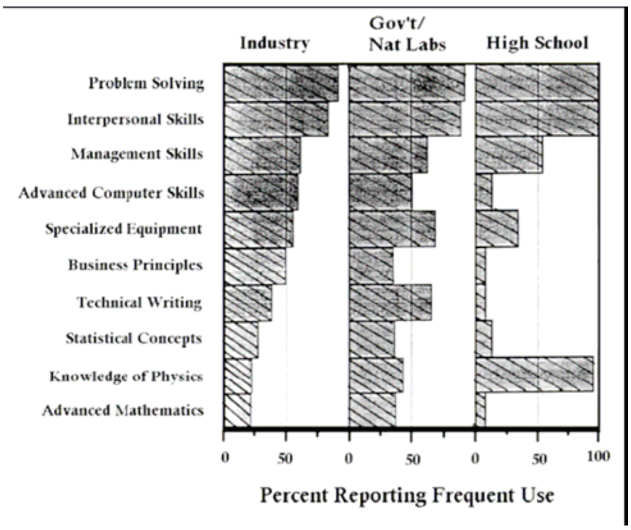

Figure 1. Report chart of skills used frequently

Modern teaching research in university education is focused on changing from a teacher-centred approach to a student-centred approach, which encourages students to take more interest in learning the discipline. Eventually, new teaching approaches will encourage active learning, will help students to develop a deep level of understanding of the content, and will help them possess some key learning skills for their future work, e.g. self directed learning, problem solving, communication, team work, etc. Problem based learning (PBL) and concept mapping are excellent modern teaching approaches that help develop these skills and are widely used in western universities.

Problem based learning

What is problem based learning? PBL is a curriculum design and a teaching/learning strategy which simultaneously develops higher order thinking, disciplinary knowledge bases and practical skills by placing the learner in the active role of practitioners (or problem solvers) confronted with a situation (ill-structured problem) which reflects the real world (King, 2005). PBL is also a style of learning in which the problems act as the context and driving force for the learning. In a PBL environment, the learner is encouraged to solve the problem, which is set in a realworld framework and is interesting, challenging and complex for the learner. In order to solve the problem, the learners have to discover or learn new knowledge either individually or together in groups, analyse relevant information obtained from different sources, think critically, and discuss the solution with others. Generally the problems used in PBL are open-ended, they do not have only one correct solution, so that the learner tends to focus on the learning process as well as obtaining a correct answer.

What are the outcomes of PBL? The outcomes of PBL are to: encourage the learner to be more active and motivated; encourage the learner become an independent learner; help the learner to achieve a deep level of understanding of the relevant knowledge; and encourage the learner to develop some key skills including problem solving, team work, lifelong learning, critical thinking and communication.

What are the advantages of PBL? PBL encourages deep learning and understanding. Students should be able to make sense of the material by integrating new knowledge with prior knowledge through the experience of solving problems, using a range of critical, cognitive and transferable skills.

What are the disadvantages? The time and resources needed for PBL should not be underestimated. The amount of content taught in this way is reduced compared to the amount that is taught in lecture-based teaching. PBL may be a new experience for teachers and learners, therefore both may require more support at the beginning. In addition, the problems must be selected carefully and professionally, so that they are at the right level for the students. The problems should be interesting and challenging for the learners.

Concept mapping

Concept mapping is a technique used for representing knowledge graphically. Knowledge graphs are networks of related concepts that are interconnected, and consist of *nodes* representing related concepts within a topic and *links* representing the relationship between concepts (King, 2005).

Concept maps can help teachers to explain complex structures and relationships of concepts, and to integrate graphically new knowledge with existing knowledge. Comparing his/her own concept map with a learner's concept map, a teacher can diagnose misunderstandings and misconceptions for the concept, and evaluate the learning results at the end of the topic. Concept maps also help learners to retain a mind map of the information they are studying, i.e. why are we learning this? Constructing one concept map before a topic and one after the topic can be used to help learners know what it is they have learned and what it is they still do not understand. By matching correctly new knowledge to their own schema, eventually learners will achieve a deep understanding of the knowledge.

Current courses and teaching strategies

As a teacher working in the Physics Department of Tsinghua University, I teach two courses (*Modern Physics* and *General Experimental Physics* (GEP)) for undergraduate students. There are about 150 students in the course of *Modern* Physics and 24 students in the *GEP*, respectively. The contents and teaching strategies of the two courses are briefly described in the following paragraphs.

The content of *Modern Physics* includes some essential concepts, principles and applications of Quantum Mechanics, Condensed Matter Physics, Modern Optics and Nanotechnology. The teaching process is currently teacher-centred in line with a behaviourist view of learning which is used widely in most Chinese universities. A student's score in the final examination is used as the assessment result. In order to increase student interest, I currently ask the students to take up a challenge: that they should submit a feasible research proposal for any topic which is related to the content of the course, and assume that they have enough financial and technological support. They must work in groups of eight. Surprisingly, most students are very active and interested in this task. The final reports submitted by each group are impressive, creative and academic. Unfortunately, at the time I was only able to discuss with each group the feasibility of their scheme, the rationale of the knowledge applied and suggest some modifications to overcome any deficiencies, because, I was unaware of how I could do more for the students.

The content of GEP includes some general physical experiments, such as Ohm's law, measurement of the speed of sound, string vibration, thermal sensor, spectrum measurement, etc. Before doing the experiments, students are asked to read the manual that describes the principle, schematic diagrams, operating procedures and data processing required. Then the students learn how to do the experiments in practice, how to use or operate some special instruments and how to perform some data processing. We have improved this over a period of time by making modifications. As a result of the modifications, a few selected experiments are now suggested for students. Students are required to do the experiments individually, taking care when operating the equipment and repeating the experiment more than twice. Meanwhile, the data processing is more complicated, so students have to process the data using a computer. Finally, students need to submit a research report that is over thirty pages.

Modification of teaching approach

Teaching of *Modern Physics*
Most undergraduate students in Tsinghua University are excellent, intelligent and active. They all have a strong background in classical physics, but they have only a little understanding for the content of *Modern Physics*. Because the content and concepts in *Modern Physics* are very abstract, boring and hard for students to learn by themselves, they might lose interest if they spend too much time learning on their own. In my opinion, the application of modern teaching strategies, such as PBL, case study and concept mapping, must be based on a basic understanding of *Modern Physics* otherwise the students will not be able to learn anything. Therefore, it is important and efficient to keep some of the good traditional teaching approaches but combine them with new modern teaching approaches.

As the students have only limited understanding of the essential concepts and content at the beginning, the teacher must organise the lecture carefully by breaking down each topic into small packages which are logically ordered and sequenced. The knowledge packages should be taught by using the traditional teaching approach in the classroom, with the students mastering each individual knowledge package before they go on to next one. As mentioned above this is the traditional teaching strategy that is currently used in my teaching. After students understand the essential concepts and content in *Modern Physics*, the modern teaching strategy of concept mapping will be introduced. Figure 2 is an example of a concept map for the topic of *Condensed Matter Physics* (CMP) in *Modern Physics* teaching.

Firstly, students will be asked to draw a concept map of the topic that has just been taught, consisting of concepts and links between the content of CMP, based on what students have learnt in the course. This concept map reflects student's mastery of the knowledge of CMP. Generally, there will be some misconceptions and deficiencies in the knowledge. The teacher will also draw a concept map of CMP. Then, a series of seminars and tutorials will be held to discuss and modify the concept map made by the student. By understanding the student's concept map, by providing new information, by explaining the relevance of certain things, by modifying the misunderstanding of concepts and by comparison with the teacher's concept map (shown in Figure 2), the teacher will encourage a deep level processing of knowledge. Students will be able to assimilate new information or knowledge, and modify or rebuild their concept map to fit in the new knowledge. Eventually, a correct and integrated understanding of *CMP* knowledge will be achieved at a deep level, and the student's lifelong learning skills will be promoted during the process.

The topics which students find challenging should be kept and developed, but some modification must be made in using the PBL approach. The range of topics should be limited to the content of *Modern Physics*, i.e. the essential concepts and techniques used in the scheme should come from the content taught. Before the teacher discusses these with the students, they will discuss them within their groups with all students being encouraged to participate. As a result of the challenging topics, the discussion process will help students develop problem solving skills as well as teamwork skills. The final assessment for this course will consist of the final examination (60%), the challenging topic (30%) and homework (10%).

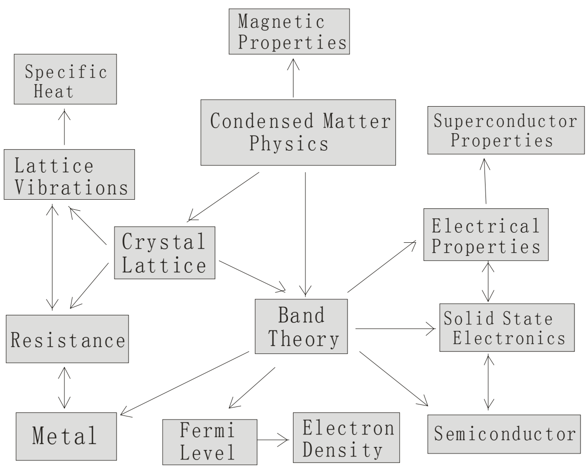

Figure 2. Concept map of *CMP*

Teaching of *General Experimental Physics*

General Experimental Physics (GEP) is an essential physical course, which aims at developing the student's ability to apply knowledge learnt in practice. As mentioned above, today's graduates are required to possess many specific skills as well as knowledge of their discipline, therefore it is also necessary to modify the teaching strategy in the GEP course. The content of the GEP course should consist of two kinds of experiments, basic experiments and advanced experiments. The purpose of basic experiments is to train student's ability to apply their physical knowledge in practice and to cultivate a good operating habit in the laboratory. The advanced experiment is similar to the selected experiment mentioned above, but the teaching approach must be modified. Firstly, students select one experiment that they are interested in, but there is no experimental manual for this course. Students working in a group will be expected to: find out what are the main concepts and principles used in the topic; design the experimental schematic diagram and operating procedure; choose which instruments are to be used; correctly connect or build the instruments required; and predict the experimental results or data. Finally, students will do the experiment based on their schematic diagram, and the feasibility of the scheme will be assessed based on the final experimental result and report. The final assessment will consist of the basic experiment of 60% and advanced experiment of 40%.

Actually, the whole process of the advanced experiment based on PBL simulates a practice topic or project that students will meet in their future work after graduation. This process is able to train and promote some key abilities and skills, such as intellectual and imaginative powers, self-learning, problem solving, team work, lifelong learning and self-assessment etc. The teacher's job in this teaching strategy is to select the experiment carefully, to provide direction when students have difficulties, and to assess and discuss the final result or data with each group.

Conclusion

The teaching strategy of PBL and concept mapping are strong motivators for students' interest and activity and in developing their learning ability and relevant skills. However, we cannot adopt these strategies without first considering the difference in the teaching environment, background of students' knowledge and the discipline in which we teach. We must analyse the content of the course very carefully, and find optimal teaching approaches for each course. When considering the courses, *Modern Physics* and *General Experimental Physics*, I believe the optimal teaching strategy is a combination of the traditional teaching approach with PBL and concept mapping.

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