Reflection on modern teaching theory and practice in physics

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Abstract

In China, many high school teachers have been aware of trends which have been taking place in teaching in Western countries, and have tried their best to make some changes. But teaching at universities does not appear to have changed. This has puzzled me for a long time.

In 2006 I was honoured to join in the *Teaching Science in English* program. A semester's study made me aware of new exciting ideas about teaching. From Mike King's class and relevant seminars I have learned about contemporary issues and research in teaching and learning in science. I have also observed teaching practices that are very different from that in China. I have gradually realised that the teaching and learning practices in China (perhaps in many Eastern countries) are similar to those used one hundred years ago (in Einstein's era) in Western countries, and which have now been discarded.

The possible application of some new teaching strategies to teaching in China will be discussed in this paper.

Modern theories about teaching and learning

Faced with the exploding knowledge of the 21st century, traditional teaching strategies (based upon the lecturer as 'expert' and the student as the passive recipient of knowledge) have been found to be inadequate for many students, because much of the knowledge they learn in university will be out of date when they complete their course. It is important to develop students' lifelong learning skills such as:

- problem solving skills;
- technique and cognitive skills;
- self-directed learning skills;
- critical thinking skills;
- communication skills;
- ability to work in teams;
- ability to seek out and assess information; and
- ability to evaluate themselves and others.

In order to achieve these aims, we should change the students' attitude towards study, making them active learners. So we must change from teacher-centred teaching strategies to student-centred ones. Modern teaching theories have been put forward to meet this change.

Theories of learning science

Different from the theories of behaviourism and developmentalism, constructivism describes an understanding of how students learn and how scientific ideas are acquired and developed. It includes the development of conceptual scientific schema, concept mapping, assimilation and accommodation of knowledge. It emphasises: individual activities decide the acquisition of knowledge; knowledge is constructed when the present knowledge is related to new; and social context is important. Knowledge is created by doing, researching and linking to the real world.

Theory of teaching that links to learning

Understanding student learning and that teaching is not in one direction; student-centred learning is encouraged. In the teaching process, the teacher is the coach and the teacher's role is to stimulate students.

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New teaching strategies have been designed to make students' active learner and developed their skills:

- curriculum designed for the future;
- problem-based learning and pedagogies;
- case study and contextualised learning pedagogies;
- use of online teaching and learning technologies and strategies;
- problem setting and solving (including individuals and groups);
- tutorials tasks;
- group tasks;
- mixed workshop;
- project works; and
- independent study tasks.

Modern teaching practices at The University of Sydney which differs from that at Qingdao Technology University (QTU)

After I arrived at The University of Sydney I observed a variety of teaching practice which obviously embodies the student-centred teaching theory and which is very different from that at QTU. Here I list some of the practice which I find strikingly different.

- Subject choice: at The University of Sydney, students can choose subjects freely until in their third year, when they choose specific subjects in which to major. There is enough time for students to develop their interests. At QTU students must undertake definite subjects as soon as they enter university.
- Time arranged: at The University of Sydney, subjects are scattered in several semesters and each lecture lasts 50 minutes. There is enough time for students to allow students to absorb knowledge gradually while staying attentive in lectures. At QTU one subject is covered thoroughly in one semester. It's difficult for students to control all knowledge of a certain subject in only one semester. Lectures lasts two hours and students become very tired and lack concentration in the second hour.
- Curriculum design: at The University of Sydney a student's interest, ability, the appropriate knowledge and necessary training are given more attention than the consistency of the curriculum. At QTU more care is taken with the consistency of the curriculum. This traditional design can expose students to a large amount of knowledge in a short time, although students can learn more knowledge in short time, it increases the students' load and there is little time to develop ability. Some experts in China have realised that curriculum consistency may bar the reform of teaching and learning mostly.
- Lecture style: teachers only choose some chapters to explain in detail. During the lecture students have opportunities to ask questions. There are more demonstration experiments in lecture. The lecture is not compulsory for students to attend. At QTU teachers must follow the syllabus strictly in order to teach all the chapters in detail. There are few demonstration experiments but more formulation concluding. Lectures are compulsory and students are required to remain silent. If a student is repeatedly absent from lectures, it would result in failure at the end of semester no matter what mark was scored in the final examination.
- 'Tutorial Workshops': there are periodic tutorial workshops in their first year to promote a deeper-level processing of learning, communication skills, and team skills. In 'Tutorial Workshops', the worksheets are designed carefully. There are three styles of worksheets: a basic introductory level and two at a more advanced level, one with a biological flavour and one with a physical or technological flavour. In the workshops students discuss questions with classmates, teachers or senior student tutors. At the end of the workshop the solutions are given to the students. At the same time students observe demonstration experiments relating to the problem. At QTU only after class are the students able to discuss questions with each other or with teachers.
- Online assignment: there are assignments for students to do online and this allows teachers to find out if the students use hints or not. At QTU we only have paper-based assignment so it's difficult to know if the students do their homework independently.
- *MatLab* is often used in second year for numerical calculations in a computational environment. It's effective at stimulating students' interest.
- Information resources: there are many ways for students to study by themselves so as to develop their self-directed skills, research skills, critical thinking skills and widen their view:
  - A large numbers of reference books in paper or online are bought by the University and made available to students.
  - Students can use *WebCT* in which they can access teachers' home pages and find many links to acquire up-to-date knowledge to supplement their classes.
- Projects: a four weeks project experiment is offered in first year. Students are required to design their own experiment. In the four weeks, teachers or senior student tutors assist the students without telling them what to do or how to do. There are five aspects to the assessment.
  - Initial and Final proposal: they are required to demonstrate to a 'supervisor' or 'funding body' that they know what they want to do and that they have a good understanding of how to do it. They must be able to argue why it is desirable or important to carry out the work, and that they are capable of doing it.
  - Laboratory work: assessed according to the contribution to the group.
  - Oral presentation (10 minutes in length) by one student in the group while other members demonstrate their experiment. They are required to state the aims clearly, describe the experiment apparatus and techniques used, present the important results, and state a conclusion.
  - Written report.
- Comprehensive assessment throughout the years of study includes many aspects.
  - Peer-assessment, self-assessment and teacher-assessment in group work such as group projects, tutorial workshops, etc. The following scales are used to rate each member:

- attends group meetings, comes prepared to class;
- completes assignments thoroughly, contributes relevant information when solving group problems;
- asks questions that promote a clearer understanding of the problem; and
- answers group members' questions in a way that promotes understanding.

o Daily assignments.
o Final examination.

Assessment is always a driving force in students' learning. Among these strategies I think the assessment of work done in groups (formative assessment) is excellent. On one hand, it can assess how the students get knowledge other than what they remember so as to develop their skills and their attitude toward study. On the other hand, it can develop students' lifelong skills, although it is a challenge to all students. At QTU we have many summative assessments to see how much of what we have taught is retained by the students. But we lack formative assessments. Perhaps it's a serious problem in develop students' many kinds of lifelong skills.

An attempt to apply some new teaching strategies in a Physics course

Concept maps

A concept map is a useful way to represent knowledge graphically, so as to relate concepts and ideas that are interconnected. It can help students identify the key and associated concepts of the problem and get a deeper understanding of the topic.

The concepts in quantum physics are very abstract, boring and difficult for students to believe or learn. At the beginning of a quantum physics course the 'photon' is a key concept but it is very different from the classical physics. It is difficult for them to believe and understand why the energy can be discrete. A concept map can be used to show how the concept of a photon was put forward historically. It will convince them that the photon is true. Another concept map is about some important concepts related to Schrödinger's Equation in quantum physics.

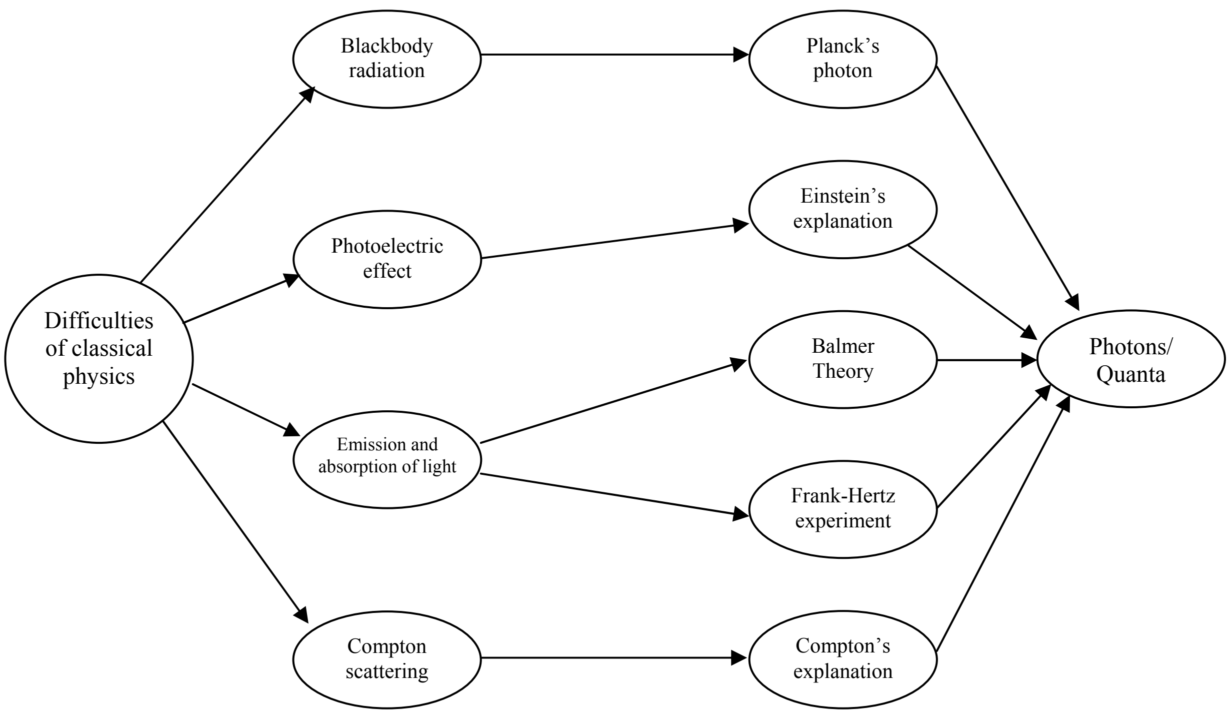

Figure 1. A concept map showing how the photon idea was put forward

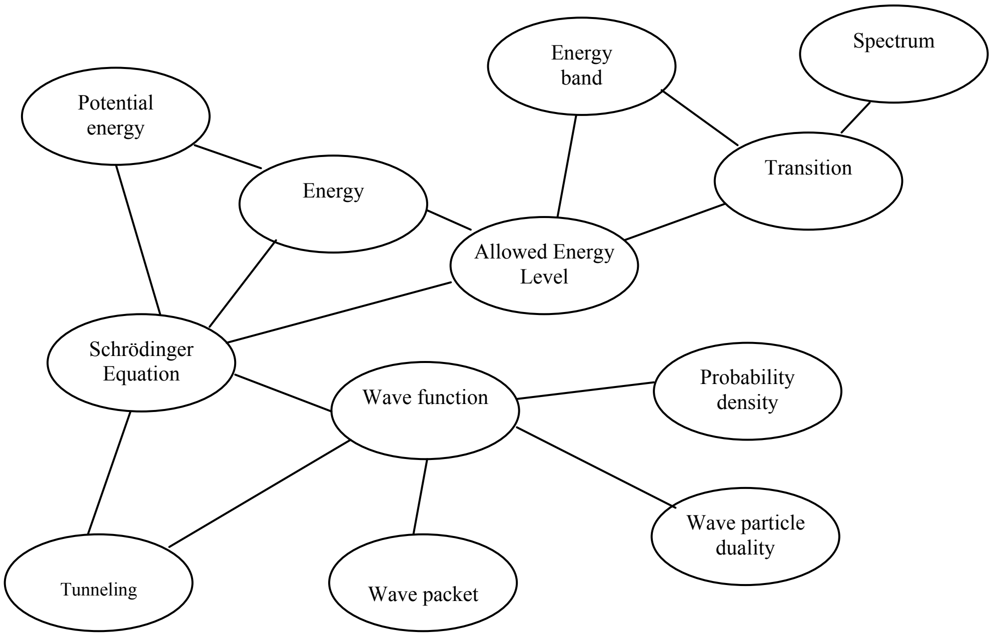

Figure 2. A concept map of Quantum Mechanics

Problem-based learning in Mechanics

PBL involves learning through tackling relevant problems. These are some of the properties of PBL.

- There is no emphasis on actually 'solving' the problem, but nevertheless provides a rich environment for learning. The aim is to learn rather than to solve the problem. In this point it is different from learning how to solve problems (problem-solving).
- There is no prior presentation of subject matter. It is different from applying knowledge to problems (project work).
- The problem should be placed in a real-world situation.
- Students discover what they have to learn towards the problem, and then learn what they need to tackle the problem.
- Interactive and cooperative learning.
- The teachers are used as experts to answer questions on parts of the theme that are not easily accessible otherwise.

Here is an example of PBL I give a class about projectile movement in Mechanics:

A body has been found on the bottom of a disused quarry. The depth of the quarry is about 30 metres. You are called by the police as an expert to ask two questions:

1. Could the body have reached the point where it was found if the person had jumped from the top of the cliff, or from either of the lower level?
2. Could the body have been thrown there from either the top of the cliff or from the first level down?

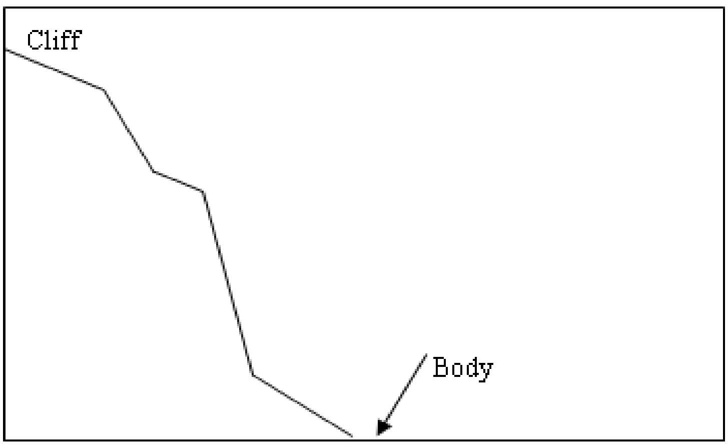

Figure 3. The 'body in the quarry' problem

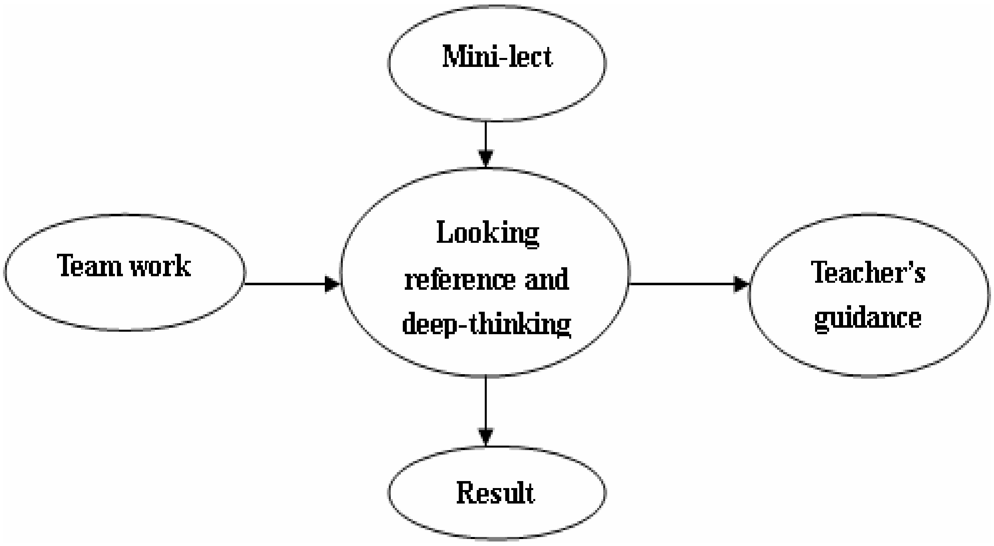

Figure 4. The process of PBL in physics teaching

Obviously it is a real problem. The concepts I want students to understand is about projectile motion. It is central to the problem I have outlined.

In order to solve the problem the students should learn about projectile motion. Then they can calculate and plot the body's trajectory under a variety of initial conditions which will help them answer the questions above. This process can develop skills such as: thinking, and group discussion. The course to solve the problem is shown in Figure 4.

In the mini-lecture I would provide them with many resources and a resource list, (such as book, article, web site etc.). While they are developing the relevant knowledge I can divide them into several workshops and give them tutorials.

Conclusion

In the paper I have discussed new theories and practice we learnt at The University of Sydney. I also have made an attempt to apply new teaching strategies in a physics course. After I go back to China I will bring these new ideas to our colleagues and try my best to improve the quality of teaching and learning in my course.

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