

Improving the teaching and learning in *Modern Physics* with contemporary strategies

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Abstract

In order to communicate new knowledge and keep up-to-date, it is necessary for teachers to be trained in contemporary teaching strategies in order to build on previous experience of teaching and learning in undergraduate physics. Based on the project of *Teaching Science in English* in The University of Sydney, a well-founded change in ideas of teaching techniques has taken place. These strategies include e-learning, independent study tasks, project work, mixed workshop, problem-based learning, case studies. In this article, I will discuss how to choose suitable techniques, such as concept mapping, case studies and mixed workshop, and apply them in the subject of *Modern Physics* which I teach to the senior students in the East China Normal University.

Key words: contemporary teaching strategies, *Modern Physics*, concept map, case study

Introduction

'The amount of knowledge that the student learned is a criterion and goal of effective teaching.' These were the most impressive words preexisting in my mind. But once I studied contemporary science teaching theory at The University of Sydney, I became aware that it is not the only principle of teaching. In addition to the selection of instructional materials that meet the needs of students, and what the teacher imparts in the classroom, there are several other factors that can influence the students' development in learning. Among the most important are the teaching strategies, which should fit the teaching and learning environment.

For example, most science courses, particularly introductory courses such as *Modern Physics* which I teach to the senior students in the East China Normal University, always emphasise discipline-centred or instructor-centred teaching. This means that the students have been exposed to great amounts of scientific information, formulas and concepts which may be unrelated and uninteresting. At the same time, the teacher could not focus on encouraging the students to learn by themselves, instead they rush to cover more and more information in the lectures. In essence, we must now realise that students learn too little of what we teach if we use the conventional teaching methods such as teacher-centred. Therefore, we must change the method of teaching and learning.

Now in my opinion, the measure of teaching is not the amount of knowledge the students learn from teachers but the learning skills which the students master. Thus, science teaching requires more attention to the teaching/learning process of moving students from their initial state of knowledge and understanding to the desired level, rather than to the content of the course. In fact, studies show that students learn best if they are engaged in active learning. Student-centred teaching is a teaching style more effective than others because it is more likely to motivate students by engaging their interest. In the future, in order to help students learn better, we not only managing change, assessment for the future, curriculum design, training the students learning skills needed, but also developing the teaching techniques needed in the classroom.

It is fortunate that I could attend the program of *Teaching Science in English* which is supported by The University of Sydney and the China Scholarship Council. I have the opportunity to access the contemporary theory of teaching science. Although it was a short time, it is one experience that I will never forget. In this article, based on the pedagogical teaching strategies (such as e-learning, independent study tasks, project work, mixed workshop, problem-based learning, case study and so on) that I learned and understood from the lectures presented by

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Dr Mike King and other professionals, I will discuss in particular how to choose the appropriate techniques, including concept mapping, case study and mixed workshop, and apply them to the subject of *Modern Physics* which I teach to senior students in the East China Normal University.

How to choose suitable teaching techniques applied into *Modern Physics* in China

Modern Physics is a one-semester service subject for the senior students with a foundation of general physics knowledge. The content of this subject usually consists of three parts: quantum physics, the theory of relativity and atomic and nuclear physics. It is full of information and concepts which may confuse the students. However, it is a useful course, especially for students in the 21st century who will develop and apply contemporary science and technology throughout their careers.

The characteristics of Chinese learners and conventional teaching methods

When considering the learning beliefs and behaviours of Chinese students, it may be that they are following the customs of the cultural environment rather than creating new rules, which may be the same when they are learning physics or other science discipline. People in China are familiar with the idea that 'knowledge can change one's destiny', but they usually don't know how to get the knowledge except from books or teachers. I think it is the result of a long term teacher-centred practice in the traditional Chinese education system. In traditional education in universities, the teachers just impart the consolidated knowledge which they had mastered themselves to the students but they don't teach the students the skills of getting knowledge and other abilities, such as finding, analysing and solving a problem. In other words, it emphasises teacher delivery rather than student learning. As a result, this traditional teaching approach often leads to surface learning and the students find the content is too abstract, boring and hard to relate to the real world.

There is a famous saying 'you must teach others how to fish but not give them fish', but it seems difficult to apply it in the teaching and learning progress in the universities in China because of various limitations. So, physics courses, at university level as well as high school level, usually use a teaching approach based on a lecture format with a few laboratory activities restricted to a verification of some physical laws. The course of *Modern Physics*, which I teach in the university, was not an exception. In fact, very soon the students would transfer perceived methods and learned contents to their classrooms.

Consequently, in the 21st century, there is a growing dissatisfaction with the quality of physics teaching and learning. It called for physical teachers to have an in-depth knowledge of physics discipline. There must also be widespread changes of teaching strategies in order to promote the students enjoying the physics better. Namely, the teacher should 'transform himself/herself from being a

"dispenser" of knowledge to being a "coach" managing the evolution of student skills' (Watts and Jofili 1998).

What the students want and what the teachers currently are responsible for

In order to solve our specific teaching and learning problems, as science teachers, we should first know what the undergraduate students want to meet the society needs and what the teachers' responsibilities for the students are at present.

I had been thinking for a long time that students in the university may expect the following:

1. High-quality teaching with clear goals and outcomes.
Besides the teacher's enthusiasm and passion for the subject, rapport between teacher and students during discussions in and out of class, clear and organised presentation of analytical and conceptual understanding of ideas, they also require a sensible mix of teaching strategies in the classroom and intellectual challenges from the teacher.
2. Better quality feedback and more appropriate assessment.
Formative assessment can drive the students to improve learning and indicate an individual's understanding of the content and their ability. In universities, students need to be provided with not only the final feedback and assessment but also a longer term assessment operated by the teacher that will cater for learning for the rest of their lives.
3. Better computer-based resources to support their learning, less onerous workloads in some but not all units-of-study.
4. Worthwhile, high-quality tutorials and laboratory classes.
5. Appropriate tasks that improve the students' ability to solve problems, interpret data, write reports and interact with others.

Having identified the most important things students require during the process of learning, we can conclude that quality learning is most likely to happen when it is:

1. student-centred, because that is where the responsibility lies;
2. cooperative in nature rather than competitive because people do not learn things best at the expense of others; and
3. a social act, shared with peers and validated by the whole learning environment, because learning is essentially a human activity.

At the same time, we can also conclude that we are responsible for the following:

1. the curriculum: what we teach;
2. the teaching strategies used: how we teach it; and
3. the learning context.

So what can I do in teaching *Modern Physics*? How can I use effective teaching strategies to enhance student learning? How can I develop the students' learning skills such as: self-directed and lifelong learning skills, research skills, communication skills, critical thinking skills and teamwork skills, through the course of *Modern Physics*?

The application of the contemporary teaching strategies in Modern Physics

During the program of *Teaching Science in English*, we were introduced to contemporary science teaching techniques such as:

- developmentalist and constructivist learning theories in science teaching and learning;
- problem-based learning technique in science teaching and learning;
- case study and contextual learning approaches in science;
- group tasks and collaborative learning;
- e-learning strategies and computer-based information searching method;
- curriculum developments in contemporary science teaching and learning.

Undoubtedly, these teaching strategies can not only enhance the learning experience but also make the student become an active learner who has developed a range of learning skills, including lifelong learning skills, problem solving skills which are essential to physics, technical and cognitive skills and personal skills.

It is my opinion, since the content and concepts in *Modern Physics* are very abstract, boring and hard to learn, the students might lose interests even if I use a contemporary but simple teaching method in the classroom. Therefore, it is important and efficient to combine several modern teaching approaches according to the basic principles of modern teaching methods, which is ‘Quality teaching should be aimed at promoting deep level processing of information in the mind of the learner’.

Strategy 1 – concept mapping

One strategy I would like to use in teaching *Modern Physics* is called ‘concept mapping’. Concept mapping is a technique used for representing knowledge in graphs. These knowledge graphs consist of nodes which represent related concepts within a topic and links which represent the relationship between concepts. When we map the graphs with information, it can be called a concept map, which is a diagram in which various forms of information are classified and their linkages shown.

The concept maps can help teachers to establish the concepts that link the various pieces of information together, to explain why the teacher is focusing on a particular issue of a topic which may fit into the overall schema, to diagnose misunderstandings and misconceptions for the concept by comparing the teacher’s own concept map with a student’s concept map and to evaluate the teaching results at the end of the topic. The concept maps also can help students to understand the more complex and sophisticated conceptual structures and relationships of concepts, to integrate graphically new knowledge with existing knowledge and to know what it is they have learned and what it is they still do not understand through constructing one concept map before a topic and one after the topic.

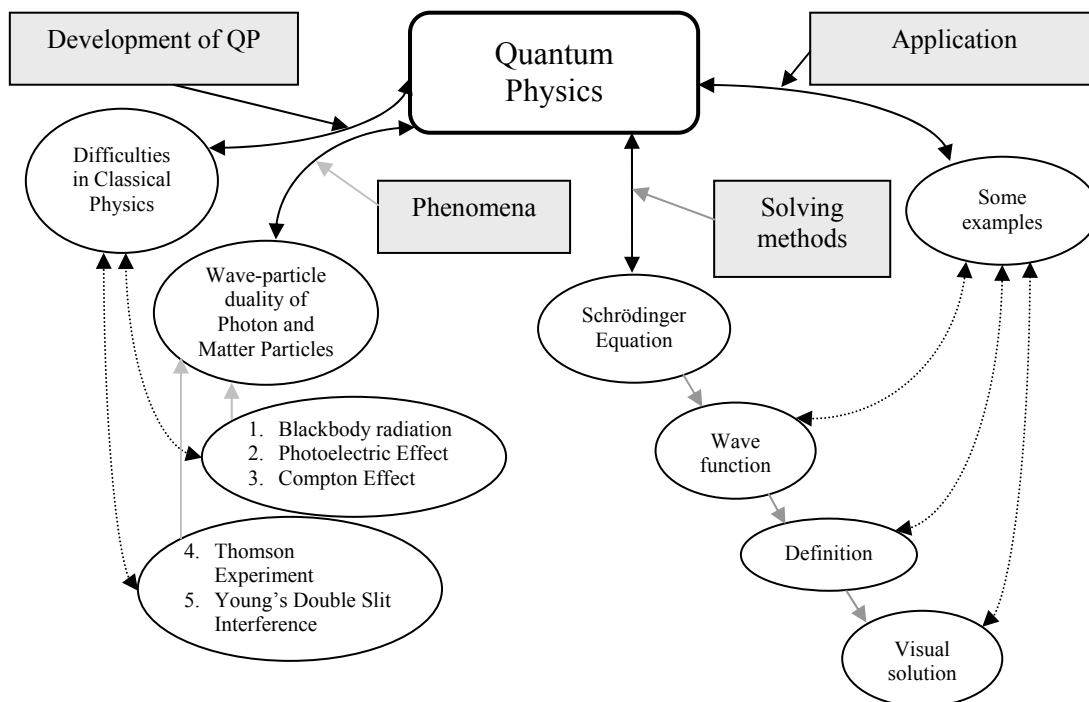


Figure 1. The concept map of quantum physics

So in the first part of *Modern Physics*—quantum physics, I will attempt to build a concept map at the beginning of my lecture in order to make the students become aware of how, why and what they are learning. Figure 1 is an example of a concept map for the topic of quantum physics in *Modern Physics* teaching, which will assist students to know the overall conceptual structure and essential content of quantum physics before they commence the topic.

Of course there are several blank links and questions in the concept map. Around this concept map, I will give a series of lectures, seminars and demonstrations in the classroom to provide new information and explain the relevance between the concepts. So during the process of teaching, the students will be asked to fill the blanks in the concept map with what they have learned in the lectures and what they can answer and conclude by themselves. Simultaneously, the students will be encouraged to a deep level processing of knowledge in their minds by assimilating new knowledge and being promoted new abilities such as lifelong learning skills.

In this teaching technique, the pivotal point is that the teacher must be clear about which are the most important parts for the student to grasp and understand.

Strategy 2 – case study

Another increasingly used strategy designed to develop a deep level approach to learning science is the ‘case study’. It can be used in introductory science courses, such as chemistry, physics, biology and environmental science. There is no fiction with case studies, just the telling of a real story about the way scientific problems have been solved in the past or are being solved at present. They can be used to encourage the learner to be active in developing particular ideas, because case studies traditionally conclude by asking some specific questions which relate to the curriculum.

Comparing with the quantum physics which is so abstract and difficult, the second part of *Modern Physics*—atomic and nuclear physics is more concrete. During a time of great technological change, the theory of atomic and nuclear physics has been successfully applied in modern society especially in 20th century. Thus, there are many cases which should be interesting, motivating and relevant to be introduced in this course to make students active seekers after knowledge and information.

The following case will be developed as an introduction to atomic and nuclear physics. In the end of 1970s, there was a famous sword named ‘Gou Jian’ found in the tomb of Yue King in Hu Bei Province in China (Figure 2).



Figure 2. The sword of ‘Gou Jian’

This sword was two thousand years old but it was shiny and untarnished when it was excavated from underground. A hair would break when it touched the edge of the sword. People were curious as to why it was still so sharp after being buried under the ground for thousands of years. In order to explain the mystery without any damage to the sword, the nuclear scientists in Fu Dan University engaged in research with all kinds of technical measures. At last they chose the analysis method of ‘PIXE (Proton-Induced X-ray Emission)’ which is a very sensitive, multi-element, and simultaneous analytical technique for accurate determinations of elemental compositions in quantities. The experiments were performed on the electrostatic accelerator and the PIXE spectra obtained from the sword indicated that the main constituent element in the sword are copper, tin and small quantities of iron, aluminium, nickel and sulfur. Figure 3 is a PIXE spectrum similar to the result of the sword.

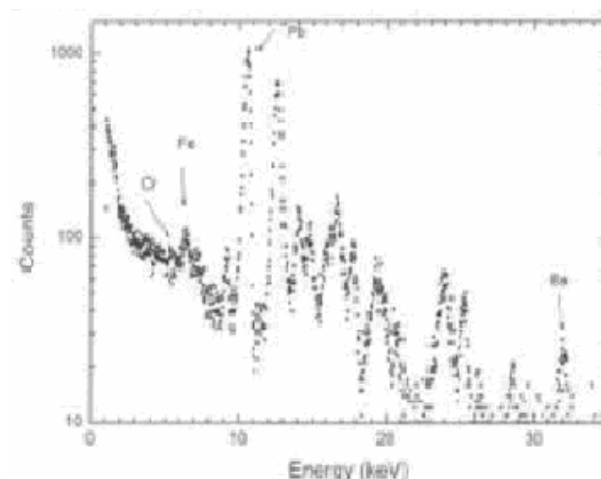


Figure 3. Typical PIXE spectrum

Subsequently, the students will be more motivated to try to find out the answers to the prospective problems in this case, such as ‘why could we obtain the constituent element through the spectrum?’, ‘What is the principle of PIXE analysis? Why it is non-destructive?’, ‘Why do the different parts of the sword have a different ratio of elements?’ etc. Therefore, on the basis of these questions I would like to provide a series of seminars or lectures to assist the students get a better understanding of atomic and nuclear physics including the structure of atoms and nuclei, binding energies, decay process, the characteristic of X-ray, the principle of accelerator and the new analysis methods using nuclear techniques.

Strategy 3– mixed workshops

Mixed workshops inserted into lectures have been introduced into large classes in the university. These workshops are good in motivating students’ active learning. They can consist of a short lecture, proposed experiments, short tutorials, hands-on demonstrations, discussions with classmates or teachers etc. There are several different aspects when compared with traditional university systems, such as:

1. group learning instead of individual learning;
2. learning with tools instead of learning without tools; and
3. object-manipulation instead of theoretical receiptal.

In the mixed workshops, the students are allowed to openly discuss and work on problems in *Modern Physics*, to explore different avenues of the solution in a free atmosphere, to interact with lecture demonstrations which they might have seen previously, as well as working through various problems together. I think this teaching strategy could capture student interest, enhance student motivation and self-confidence and allow students to learn complex context. In addition, the students can be expected to improve the independent learning skills and cooperative problem-solving ability. The mixed workshop has been successful at The University of Sydney and I believe it could also be suitable for the Chinese students. It requires the teacher to have some special skills on how to use a constructive learning environment approach to the physics content and how to direct the students on the learning activities.

The challenges in the future

As teachers, we must think how to make the students participate in the learning process, to think and learn more actively. However I am realistic enough to know it is not going to be easy, no matter which strategy I apply in the future, because of a number of perceived difficulties:

Knowing students and knowing ourselves

In China, the number of students is very large and different students have different needs. It is too difficult for the teacher to be certain what the students want and what skills and attributes we wish our students to have. We should not imagine that we can adopt the optimal strategies without considering the background of students' knowledge, the difference between learners and the analysis of the discipline in we will teach.

Therefore, no matter how difficult it is, we still need to think about it, because only once we know what we want to achieve and what skills we want our students to have, can we address teaching strategies which might achieve this.

More real demonstration in the classroom

In order to help the students in conceptualising physics models and gaining the prospective abilities, we should supply the students with appropriate pedagogical tools and hand-on demonstrations during the lectures or in the workshops. At present in the university in China, it is difficult due to some widely recognised problems such as time of lecture, ability of teacher, shortage of equipment and limitation of discipline.

Summary

These approaches involve substantial modifications in teaching methods, as well as in the role of the teacher. All contemporary teaching strategies suggest that teacher-centred styles should be replaced with student-centred teaching approaches to improve the teaching/learning process significantly. According to the characteristic of the subject of *Modern Physics*, I focus on the teaching strategy of concept mapping, case study and mixed workshop which can strongly motivate the students' interest and activity and develop their learning ability and relevant skills.

I believe that after I have applied some contemporary teaching strategies in the course of *Modern Physics*, I will be able to say the words in the famous motto 'We don't just want to make you a triathlete; we want you to know how to be a triathlete'.

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