# Physics is fun, exciting and simple

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## Abstract

Contemporary teaching and learning strategies are introduced into *University Physics* to make it more exciting. It is argued that students can develop practical skills that they need in the future as well as conceptual understanding of physics through carefully designed learning events in this course.

## Introduction

During February to June 2004, I had the opportunity to participate in the *Teaching Science in English* program at the University of Sydney. This professional development program is designed to enhance skills in the teaching of Science in English. In this program, we were introduced to contemporary issues and research in the area of teaching and learning (King 2004), including:

- constructivist learning theory in science teaching and learning;
- problem based learning approaches to science;
- contextual learning approaches in science;
- student-centred and collaborative learning practices in science;
- the use of online learning approaches; and
- curriculum development in contemporary science teaching and learning.

During the study, we not only listened to the lectures about these theories, but also experienced and enjoyed the contemporary teaching strategies, such as group work, individual and peer presentations, problem based learning, etc. These strategies make the students think, be active in learning, and be responsible for their own learning. I have drawn a lot of inspiration and begun to reflect on physics education. I think physics is fun, exciting and simple. But many of my students do not think so. They are not even interested in studying physics. Where is the problem?

In this paper, the problems that we are facing in teaching university physics are analyzed and teaching strategies are redesigned to solve these problems. New problems that will arise in implementing these teaching strategies are anticipated and the possible solutions are also given.

## Current situation of *University Physics*

*University Physics* at the Beijing Institute of Technology is a two-semester course that has five modules: mechanics; thermal physics; waves and optics; electromagnetism; and quantum physics. This course is compulsory for first year engineering major students. For most of the students this will be the only formal physics course they will undertake at the university level. The course aims to help students develop conceptual understanding of physics and build strong problem-solving skills.

The current methods of teaching physics to first year students are lectures and laboratory. However, *University Physics Experiment* is a separate course from *University Physics*. So we actually only deliver lectures in this course. The total lecture time is 128 hours over two semesters with 4 hours each week. Multimedia techniques are used to deliver more information in lectures. In the assessment, the final examination is in closed-book written form and contributes 85% to the final mark, assignments contributing 15%. Therefore the current teaching methods are essentially teacher-centred.

## Problems that we are facing

First, since these students will not major in physics, they do not understand why they have to study physics. We keep telling our students that learning physics is an excellent way to develop logical thinking, observation and experimental skills, and so on. But it is too abstract. Students still cannot see the relevance of this course to them.

Second, students seldom have the opportunities to interact with their teachers in a very large class. Usually, we have over two hundreds students in one class. They are used to being spoon-fed information by teachers. The atmosphere in the class is not very interactive.

Third, traditional physics instruction puts great efforts into the drill and practice of numerical problems that require the routine application of formulae and equations for solution (Tao 1999). Many of these problems demand more of students' mathematical skills than their qualitative understanding of physics concepts and principles. Some students are even frightened by mathematics. So mathematics could be a formidable barrier for students to enjoying the beauty of physics.

Finally, many Chinese students have done advanced physics in high school, especially mechanics. Therefore when we start to teach mechanics as a review, some of the students think it is boring because there is not much new information in it.

## What can we do to change the current situation?

**Making learning relevant to students**

You cannot teach anybody anything if they do not wish to learn it (King 2004). It doesn't work if we only tell our students they must learn something. We must tell them why they should learn this. We have to make the course relevant to students, and teach what students really need. What do students really need? It is obvious that they not only need the discipline knowledge that we are currently teaching them. Much of the knowledge they learn in university will be out of date when they leave us because of knowledge explosion. So it is reasonable when students complain that they seldom use what they learned in university in their jobs. But they do have to prepare something for their future careers.

In a survey of 200 leading European companies that employ science graduates (Sheffield University 1996), they were asked a question: 'What skills do you want your new science graduates to have when you employ them?' The answer was:

- oral communication;
- teamwork;
- enthusiasm;
- motivation;
- initiative;
- leadership skills;
- commitment;
- interpersonal skills;
- organisational skills; and
- foreign language competency, etc.

These are the skills required by society. So students should have these skills when they enter the employment market. But where and how can they get these skills? The answer is during their studies. We should provide suitable courses to students, not only to communicate the discipline knowledge, but also to develop these skills. If we build up the connection between the courses that we are going to give students and their real needs, i.e., their future careers, they should have much more interest in the courses. Therefore, I redesigned the teaching methods in my course to provide training in these skills for students.

**Workshop tutorials and case studies**

When we deliver lectures in a very large class, the interaction between the lecturer and students is far from satisfactory. We ask questions, only a few students respond to them. Most students just sit back in the classroom and wait to be spoon-fed information. They are not involved in the teaching and learning process. They are not thinking! There is a saying that it is no use learning without thinking. Finding ways to make students think is pivotal in the teaching and learning process. Besides, students cannot see the relevance of physics when we keep giving them lots of laws, principles and derivations in lectures, and this content discourages students from studying it. It only encourages rote learning; students cannot develop any of the practical skills they need in the future. To solve this problem, I will choose a small class (below 40 students) and introduce workshop tutorials and case studies into the course. Workshop tutorials provide a more interactive, cooperative and student-centred classroom environment to capture student interest and enhance student motivation and self-confidence (Sharma, Millar and Seth 1999). Case studies tell a real and complete story, are usually interdisciplinary and set in a real world context, have academic and professional significance, and have social implications (King 2004).

The following are some examples that we can use in various modules of *University Physics*:

- Mechanics: pulleys, roller coasters, tides, rockets, satellites;
- Thermal physics: thermometers, the steam engine, refrigerators, air conditioners;
- Waves and optics: musical instruments, cameras, optical fibres, telescopes, 3D movies;
- Electromagnetism: lightning rods, photocopiers, radios, televisions, electric motors, electric generators, magnetic levitation; and
- Quantum physics: electron microscopes, scanning tunneling microscopes, lasers, X-rays.

Looking at these cases, we cannot imagine a modern life without physics. They are interesting, relevant, motivating and related to students' professional and real worlds (King 2004). When students work on these case studies, they are not required to do much mathematical work. We encourage students to develop conceptual understanding of physics concepts and principles and help them learn how to think like a physicist. I think that through these examples, students will find that physics really is fun, exciting and simple, and useful in everyday life.

Usually when we teach physics we give lectures first, then mention these cases as examples. Now we can change the order. Figure 1 shows the learning cycle. First, students attend workshop tutorials and are given the case studies. According to the complexity of the examples, they can work in teams of four or individually. If they encounter difficulty, they can seek help from the tutors. The role of the tutor is to help students to think, rather than simply giving them the answers. After the tutorials, formal lectures will be given to help students establish a systematic knowledge base. Because students are listening to the lectures with questions, they will be more involved in the teaching and learning process: they will be thinking. After that, students are asked to write a report on the case study. Then we move on to the next learning cycle.

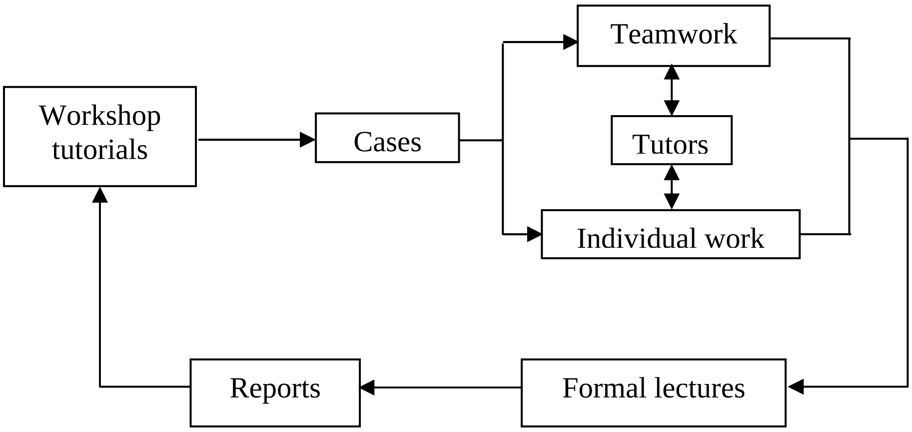


**Figure 1**. The learning cycle

**Problem based learning in Mechanics**

Problem based learning (PBL) is one of the most exciting and powerful educational options that has appeared in the last 30 years (Woods 1994). PBL is a learning environment that embodies most of the principles that are known to improve learning: active, cooperative, prompt feedback, tailored to student's learning preferences. It forces the students to learn the fundamental principles of the subject in the context of needing it to solve a real world problem. Hence, information is learned in formats different to the traditional subject-based style.

Since PBL is a relatively new approach in teaching *University Physics* at BIT, it is challenging to both students and the teacher. At the beginning, I would like to try one problem in Mechanics because students have acquired the basic knowledge needed to solve a real-world problem in high school. Concept mapping will be integrated into PBL to help students identify the key and associated concepts of the problem and acquire a deeper understanding of the topic and clarification of any prior misconceptions (Lanzing 1997). The following is a problem about flying over the Yellow River.

*Hukou Waterfalls, China's second largest waterfall, is in the middle reaches of the Yellow River. Its average width is 30 metres and the maximum width can be over 50 metres in the flood season. In 1997, a Taiwan actor, Ke Shouliang, jumped over the Yellow River at Hukou Waterfalls with his racing car to celebrate the return of Hong Kong to the People's Republic of China. The flying distance was 55 metres. In 1999, another young Chinese man, Zhu Chaohui, jumped over the Yellow River at the same place with his motorcycle to celebrate the return of Macao to her motherland. And right after that, he and his beautiful bride held their wedding. Now, your physics teacher, Tom, wants to get his name in the Guinness Book of World Records by flying over the Yellow River at Hukou Waterfalls by riding a bicycle or skateboard. Being his technical engineers, you are supposed to design the tracks and train him so as to make this event a successful one!*

**Figure 2**. Hukou Waterfalls of the Yellow River

**Figure 3**. Ke Shouliang flew over the Yellow River

**Figure 4**. Zhu Chaohui flew over the Yellow River

**Figure 5**. The wedding

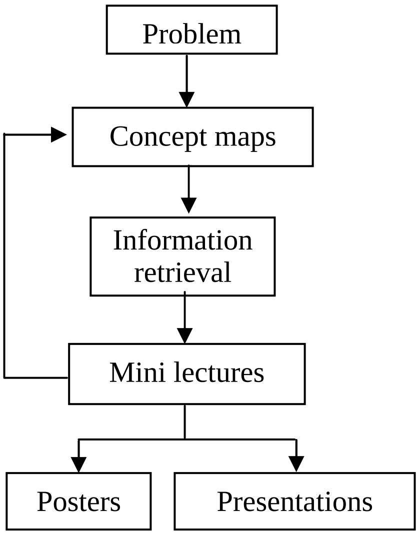


**Figure 6**. Teaching and learning processes in PBL

Flying over the Yellow River is very famous in China. Students will get excited about this problem. They work in teams of four and have three weeks to solve it. Figure 6 illustrates the teaching and learning process. Before they solve the problem, they should brainstorm their own concept maps based on their previous knowledge. Then they have to find some relevant information from the textbook, library, Web and other resources. In the process of trying to solve the problem, they may find their results are quite different from the information given in the problem and from other resources. For example, based on the information they learned in high school, the flying distance should be far more than 55 metres if the initial velocity of the car or motorcycle is 120 kilometres per hour. They might be confused. They might be eager to find the reason. Now, the students are challenged. After attending a mini lecture about air resistance, they will appreciate the deficiencies in their prior knowledge. They need to learn more in trying to solve a real world problem. After this challenge, students will never find the review part of mechanics boring. During the three weeks, I will give four mini lectures to introduce some basic physics concepts to help students solve the problem. The four mini lectures are:

***Displacement, velocity and acceleration***

We begin our study of physics with mechanics, the study of the relationships among force, matter, and motion. In order to study motion, we have to learn how to describe it. The part of mechanics that deals with the description of motion is called kinematics. The general method for describing motion is using the physical quantities displacement, velocity and acceleration. These quantities have simple definitions in physics; however, those definitions are more precise and slightly different than the ones used in everyday language. In this session, students are encouraged to use calculus to find the relationships among displacement, velocity and acceleration.

***Newton's laws of motion***

Dynamics is the study of the relationship between motion and the forces that cause it. The principles of dynamics are Newton's laws of motion, and these are the foundation of classical mechanics. Newton's laws are very simple to state, yet many students find them difficult to grasp and work with. The reason is that before studying physics, students have developed a set of 'common sense' ideas about motion and its causes. But many of these 'common sense' ideas do not stand up to logical analysis. In this session, we try to help students to recognize how 'common sense' ideas can sometimes lead us astray, and how to adjust our understanding of the physical world to make it consistent with what experiments tell us.

***Air resistance***

In high school, students deal with projectile motion with an idealised model that does not include the effects of air resistance. In fact, the concept of idealized models is extremely important in all physical science and technology. We always use idealised models when we apply physics principles to complex systems that would be too complicated to analyse in full detail. However, to make an idealised model of the system, we have to be careful not to neglect so much that it will not work in the real world. In this session, students will see that air resistance has a very large effect and is not always negligible.

***Work and energy***

Newton's laws of motion allow us to analyse many kinds of motion. However, the analysis is often complicated, requiring details about the motion that we simply do not know. Yet there is another, sometimes more powerful method for analysing motion. This new method uses the ideas of work and energy. In this session, students will learn the different forms of energy that are involved in this problem and how energy relates to the concept of work. At the end, they will gain a deeper understanding of the concepts of energy and the conservation of energy.

After we have finished all the mini lectures, students will be required to draw another concept map and to compare the new concept map with the previous one. A concept map can show how the key concepts linked to the problem correspond to the four mini lectures (Figure 7). Through the comparison of the new concept map with the previous one, students can find that their understanding of physics is improved. At the end of the third week, students can use posters to illustrate their solutions in detail. And finally, each group will give a presentation to introduce the main ideas of their solution.

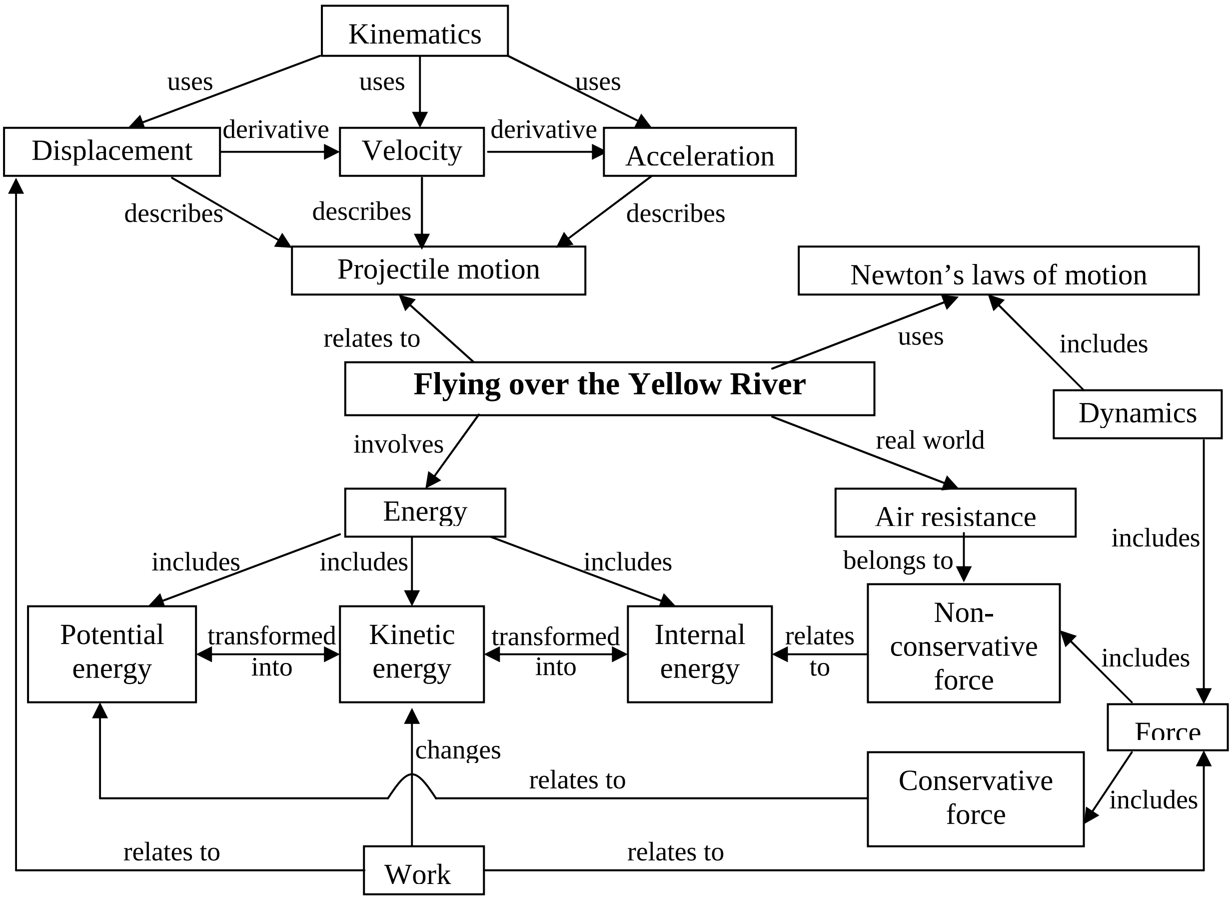


**Figure 7**. Concept map of the Yellow River case study and four associated mini lectures

**Bilingual teaching**
I am going to deliver this course in English as well as in Chinese. Lecture notes and study materials for cases and the problem will be in English. Lecturing will be bilingual to help students understand some key concepts. Students are also encouraged to discuss and give presentations in English.

**Assessment**
Assessment has been found to shape how much, how (their approach), and what (the content) students learn (Scouller 1998). If we want students to develop communication skills, teamwork skills, lifelong learning skills, etc., testing them only on the factual subject knowledge is obviously inappropriate and students still tend to employ a surface approach to learning. New teaching methods require new assessment systems (Table 1). In the new assessment system, the final examination is still in closed-book written form but only contributes 50% to the final mark to test the systematic discipline knowledge. Assignments contribute 20% to assess their learning processes. Reports on case studies contribute 10%, group presentations contribute 10% and posters contribute 10%. Reports, group presentations and posters have been added, and I also want to introduce peer-, self- and instructor-assessment in the three new tasks. Hopefully this new assessment system can encourage students to adopt a deep approach to learning.

**Table 1**. Comparison of the future assessment with the current one

| | **Current** | **Future** |
|---|---|---|
| Final examination | 85% | 50% |
| Assignments | 15% | 20% |
| Reports | NA | 10% |
| Group presentations | NA | 10% |
| Posters | NA | 10% |
| Total | 100% | 100% |

## What skills can students acquire from the course?

Students can acquire various skills in addition to physics knowledge in this course. In workshop tutorials, students work in cooperative learning groups. If they want to be successful, they have to learn how to collaborate rather than compete with each other. Their team work, interpersonal, leadership and organisational skills will be greatly developed. For oral communication skills, students can practice in group discussion and delivering presentations.

When students work on the case studies and problems that are related to real life, they will find physics is relevant to them and such learning events can arouse their enthusiasm, motivation and initiative in learning. Since this course is delivered bilingually, students may be attracted by the opportunity to improve their English language skills. It is not possible for students to acquire all the skills they need in only one course. However, we need to allow students to practice them.

## New problems and possible solutions

New problems will arise in implementing this new teaching plan. One major problem will be the conflict between the contemporary and traditional teaching approaches. At my university, engineering students are encouraged to attend a physics contest every year. If I adopt the new teaching strategies, new materials need to be put in while something else, such as numerical problems that demand more of students' mathematical skills, need to be dropped off because of time limitation. My students may be disadvantaged in such a contest that is designed for testing students taught in the traditional way. Senior management and my colleagues may not want to take the risk to let me try something new. So getting their understanding and collaboration is the first thing I need to do after I return to my university. I plan to organize some seminars on modern education theories and contemporary teaching and learning approaches to win their hearts and minds. In addition, this course will be optional for students at the beginning. The students enrolled in this course still need to attend the mainstream physics course so that they do not have to give up anything. But they can improve their English and practice the skills they will need in the future in this course. Bilingual teaching and contemporary teaching and learning strategies will be highlighted in the course description.

Another main problem is that students need to adapt themselves to new approaches to learning. They are more accustomed to the 'spoon-fed' teaching approach during their studies in school. Therefore, they are used to adopting superficial approaches to learning, such as rote-learning and formula-fitting strategy to problem solving. The new teaching strategies encourage the development of skills such as teamwork, critical thinking and self-directed learning. They should be more responsible for their own learning than before. Some students may be overwhelmed by the extra efforts needed to catch up in the course. So helping those students to adjust to new learning approaches is crucial to ensure the success of the course. I plan to give students an orientation lecture to explain what I am going to do and what they can get in this course. I can also share the experiences that I gained in the *Teaching Science in English* program with them. During the course, cooperation among students will be encouraged and this will be considered in the assessment. For example, all the members in one group will get the same mark for reports, presentations and posters. The group in which each member gives a good presentation will have a high mark.

## Conclusion

New trends in education incorporated the idea that students must be active participants in the learning process and responsible for their own learning. Students should develop generic skills for lifelong learning because we are in a rapidly changing, knowledge-based society. Contemporary teaching and learning strategies can meet these requirements and should be introduced into our teaching practices. We will certainly confront various problems when we try something new. But everything has its beginning. What we need do is to introduce contemporary teaching and learning strategies into our teaching step by step to face the challenge of the future.

## Acknowledgements

I would like to thank the China Scholarship Council, the University of Sydney Faculties of Science and Education, School of Physics and The Centre for English Teaching for their support. I also want to extend my special thanks to Associate Professor Mike King and Associate Professor Mary Peat for introducing me to contemporary education theories and approaches to teaching and learning. This article has benefited from valuable discussions with Associate Professor Tim Bedding, Dr Mike Wheatland, Dr Manjula Sharma, Dr Ian Cooper and Dr Mei Zhonglei. Review of the manuscript by Associate Professor Tim Bedding is gratefully acknowledged.

## References

King, M. (2004) Course delivered to Teaching Sciences in English. A collaborative project between the China Scholarship Council and the University of Sydney.

Lanzing, J.W.A. (1997) The concept mapping homepage. http://users.edte.utwente.nl/lanzing/com_home.htm.

Scouller, K. (1998) The influence of assessment methods on students' learning approaches: multiple choice question examination versus assignment essay. *Higher Education*, **35**, 453-472.

Sharma, M.D., Millar, R. and Seth, S. (1999) Workshop Tutorials: Accommodation student-centred learning in large first year university physics classes. *International Journal of Science Education*, **21**(8), 839-853.

Sheffield University (1996) *Characteristics significant to recruiters*. Personal Skills Unit.

Tao, P-K. (1999) Peer Collaboration in Solving Qualitative Physics Problems: The Role of Collaborative Talk. *Research in Science Education*, **29**(3), 365-383.

Woods, D. (1994) Why PBL? Improving learning and selecting a version of PBL that is suitable for you. In D. Woods (Ed.) *Problem-Based Learning: How to Gain the Most from PBL*. Ontario: D. Woods.

Young, H.D. and Freedman, R.A. (2004) *University Physics: with Modern Physics*. 11th ed. San Francisco: Pearson Addison Wesley.