

Using contemporary education strategies and approaches to redesign *Classical Electrodynamics*

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Introduction

Over the last few decades, in Europe, the United States, the United Kingdom and Australia, increasing numbers of higher education teachers and researchers have been concentrating on how to improve the quality of teaching and learning. Innovative experimental work has resulted in the formulation of a number of teaching and learning theories, strategies and approaches. These theories, strategies and approaches have one common idea: student-centred teaching and learning. The so-called student-centred approach means that teachers should think about how the learners learn and make the students actively involved in the teaching process. By using relevant strategies and approaches, many teachers have successfully fostered high quality students. With the development of higher education in China, our education committee has instructed university teachers to pay more attention to teaching and learning methodologies in order to improve the quality teaching and learning. More and more Chinese teachers have recognized the importance of teaching and learning methodologies and are actively applying them to their classes. But it is still only a beginning. This paper will first give an overview of mainstream contemporary education ideas, theories, strategies and approaches, then introduce how to apply these approaches to the curriculum of *Classical Electrodynamics*. Finally, several crucial problems about teaching and learning in this subject will be discussed.

Overview of contemporary mainstream education methodologies

In our modern society, the governments of most countries provide huge amounts of money to support and develop their higher education systems each year. Why? What does the government expect from higher education? Our answer: to produce graduates meeting the requirements of society. Yes, absolutely! Hence, a series of issues arise.

1. What are the requirements of today's society?
2. What aims of teaching and learning will fulfil these requirements?
3. What is the core idea of teaching and learning to realise these aims?
4. What set of approaches to teaching and learning will assist?
5. How can they be applied to the curriculum?

Therefore, to improve the quality of teaching and learning, we face a series of problems. The relationship between these problems can be shown in the following diagram, Figure 1. It illustrates the interactions between society, students and higher education.

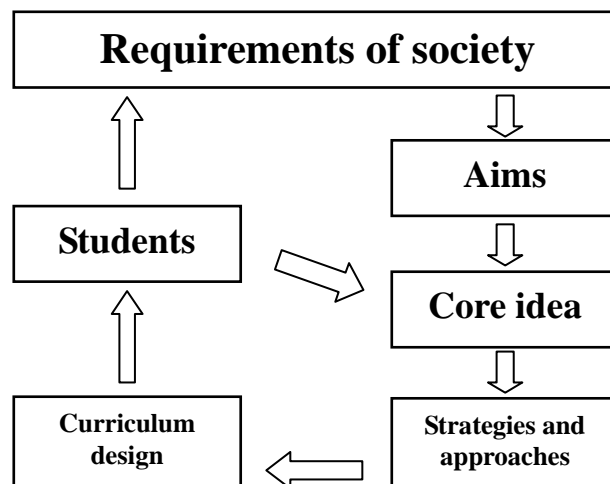


Figure 1. Interactions between society, students and higher education

We can see that the aims of teaching and learning are determined by the requirements of present society. But the core idea of teaching and learning is determined by both the students and the aims of teaching and learning. Learners are the main body involved in the teaching and learning process, they are also the most important and complicated factors. Therefore we must consider the characteristics of learners in the teaching process. Under the core idea of teaching and learning, relevant strategies and approaches can be presented and applied to the curricula. After having been taught the designed curricula, ideally, students would possess abilities and skills to satisfy the requirements of society.

What are the requirements of today's society?

As we know now, our world is changing rapidly, for example, consider technological development, and the information explosion. According to the Review of Australian Higher Education (2002) 'students face a world in which much of the work they will do has not yet even been imagined. The pace of technological change and the growing access to new technologies means that individuals will constantly need to reinvent themselves'. In other words, students are asked to have the ability to fit into and push social development.

What are the aims of teaching and learning to fulfil society's requirements?

How can the requirements of society be met? What are the aims of teaching and learning? According to What Higher Education in Science Should Deliver 2000, CNAA, UK and Allen (1991), a university graduate should have developed:

- intellectual and imaginative powers;
- understanding and judgment;
- communication skills;
- cooperation skills;
- problem-solving skills;
- a broad perspective on their discipline; and
- an inquiring, analytic and creative approach.

So, these abilities and skills are what students should gain from a university education.

What is the core idea of teaching and learning to realise these aims?

Universities need to deliver not simply specific knowledge and specific skills but also the attitudes, aptitudes and problem-solving skills, which will sustain learning throughout life. This is the difference between traditional and modern teaching approaches. First of all, we must change the dominant teaching methodology from teacher-centred to student-centred.

According to *USA National Board of Teaching Standards in Higher Education* (2000) teacher-centred teaching can generally be defined as only transmitting specific knowledge and specific skills to the students. In student-centred teaching, teachers should think about how the learners learn and make the students actively take part in the teaching process.

But how and what do the teachers do? The *USA National Board of Teaching Standards in Higher Education*, 2000 also presents standards for teachers.

What are accomplished teachers? According to the literature, accomplished teachers have a rich understanding of the subject matter they teach and appreciate how knowledge of their subject is created, organised, linked to other disciplines and to real-world settings. The teachers must also develop critical and analytical capacities in their students and command specialised knowledge of how to convey and reveal subject matter to their students. They will have pedagogical content knowledge. They will command a wide range of teaching strategies that enable them to organise, adapt and present the curriculum in ways that take account of the specific context in which they teach and of the way students learn. Just as an ancient Chinese proverb advises: teach a novice fishing rather than giving him a fish. But we must also notice that student-centred teaching does not mean lowering the standard and quality of the students' learning. Teachers are still in the dominant position, responsible for the design and control of the teaching and learning processes. Teacher should take suggestions from students that are helpful to their learning and need not satisfy the students' every requirement.

What set of approaches to teaching and learning will support the aims?

In order to support the core idea, we must present and develop a set of strategies and approaches to teaching and learning. A brief introduction of teaching and learning strategies and approaches is taken from the literature.

- Concept mapping
- Concept changing
- Problem-solving
- Problem based learning
- Case studies
- Socially based issues
- Workshop tutorial
- New technical aid teaching
- Library based learning
- Web-based learning
- Computer modelling

The first five strategies and approaches will be discussed because they are used in *Classical Electrodynamics*.

Concept mapping involves making a network of concepts. There are many important concepts in *Classical Electrodynamics*, so to give, or ask the students to make, a concept map will be helpful to the students' learning.

Concept changing often happens in the process of teaching new concepts. Students must alter misconceptions to new, correct ideas. For example, in special relativity, there are many new concepts that are very strange in everyday life. So we must lead students to change their misconceptions.

Problem-solving skills will be developed in this course, because there are a lot of logical and mathematical problems for students to solve.

Problem based learning involves designing a real-world problem and then asking students to learn by engaging in the process of solving the problem. In theoretical physics courses, because most concepts are abstract, there are very few real-world problems that can be used. Many theories are based on the abstract and complicated experiments done in special laboratories.

Case study is a strategy to give students real examples, the history of disciplinary development and biographies of famous physicists to excite the students' interest and illuminate the students' critical and creative thinking. In *Classical Electrodynamics*, there are many excellent cases to help the students to learn. So the case study is very useful in this course.

How to design a curriculum coherently using these approaches

Teachers should take an integrated approach to curriculum design. A cycle of teaching and learning includes four factors that can be seen in Figure 2. First, we apply relevant teaching and learning strategies and approaches to the student-centred teaching and learning process. Teachers want to achieve the goals determined by the requirements of society, through student-centred teaching and learning. But these goals are not easy to reach, teachers must get feedback from students through quizzes, the final examination, assignments and assessments. Teachers should adjust and modify their strategies and approaches on the basis of this feedback. At that time, the first cycle is finished. This cycle can be repeated over and over again. Progressively, the qualities of teaching and learning will be improved.

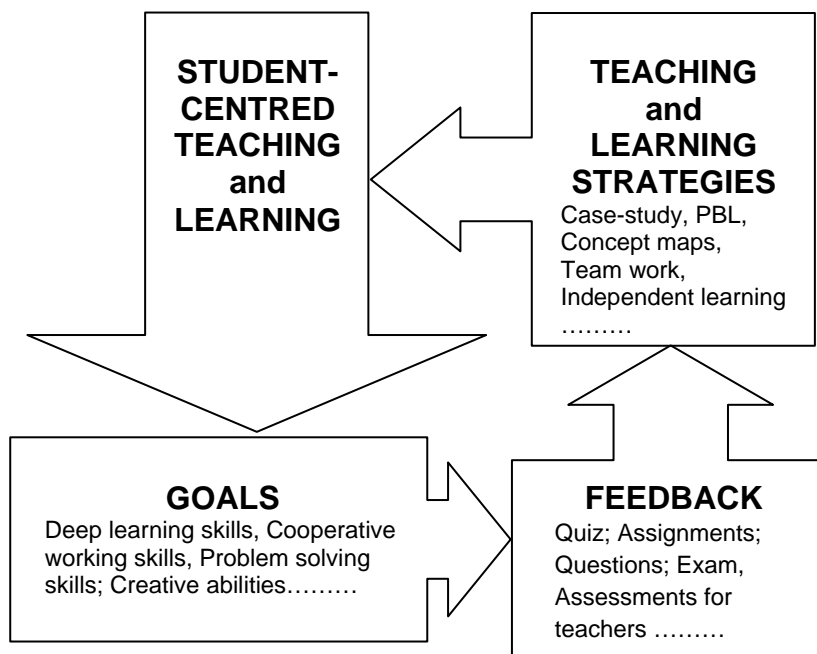


Figure 2. A map of the teaching and learning loop

Redesign of *Classical Electrodynamics* using contemporary teaching and learning approaches

As a Chinese proverb says, all things are most difficult in the beginning. Before class, teachers must communicate with the students to understand their study situation and background knowledge. First: talk with the mentor to determine previous knowledge, especially their mathematics and physics levels. Second: talk with some students about what they are interested in and what difficulties they are having. Third: adjust the course level and content according to the students' situation.

Next I will give the strategies for each chapter according to the content.

Chapter 1. Vector Analysis

Content

- 1.1 Vector operations
- 1.2. Gradient
- 1.3. Divergence and Gauss' law

- 1.4. Curl and Stokes' theorem
- 1.5. Curvilinear coordinates

Strategies

- 1. Review assumed knowledge and learn the new material, ensuring all students have the same baseline knowledge.
- 2. Concept map, (Figure 3). I will give the students the concept map before the class to let them know the structure of this chapter.

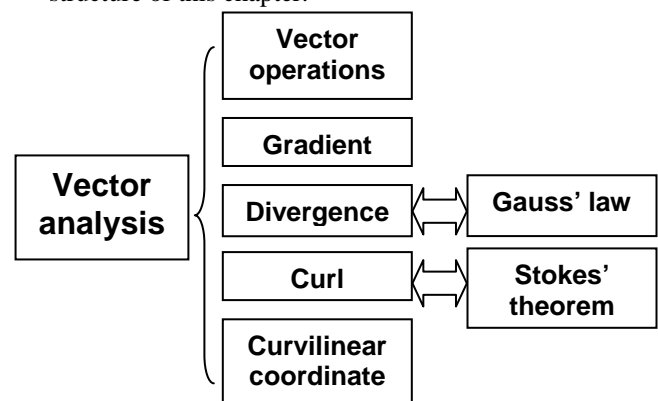


Figure 3. Concept map of Chapter 1

Chapter 2. Static Electromagnetic Field Theory

Content

- 2.1 Charge and Electric Fields
- 2.2 Current and Magnetic Fields
- 2.3 Maxwell's Equations in Vacuum
- 2.4 Maxwell's Equations in Media
- 2.5 Electromagnetic Boundary Conditions
- 2.6 Electromagnetic Energy and Energy Fluid

Strategies

1. Case study. This chapter is the beginning of *Classical Electrodynamics*. I will tell the students the history of

electromagnetic development and some stories about famous physicists and great events in electromagnetics to excite their interest and teach them how to think critically and creatively.

2. Concept map. In order to help the students understand electromagnetic theory, I will ask them to give me the map of Maxwell's Equations.
3. Summary. In order to develop the students' ability to integrate knowledge, I will ask the students to give me a summary of the chapter.

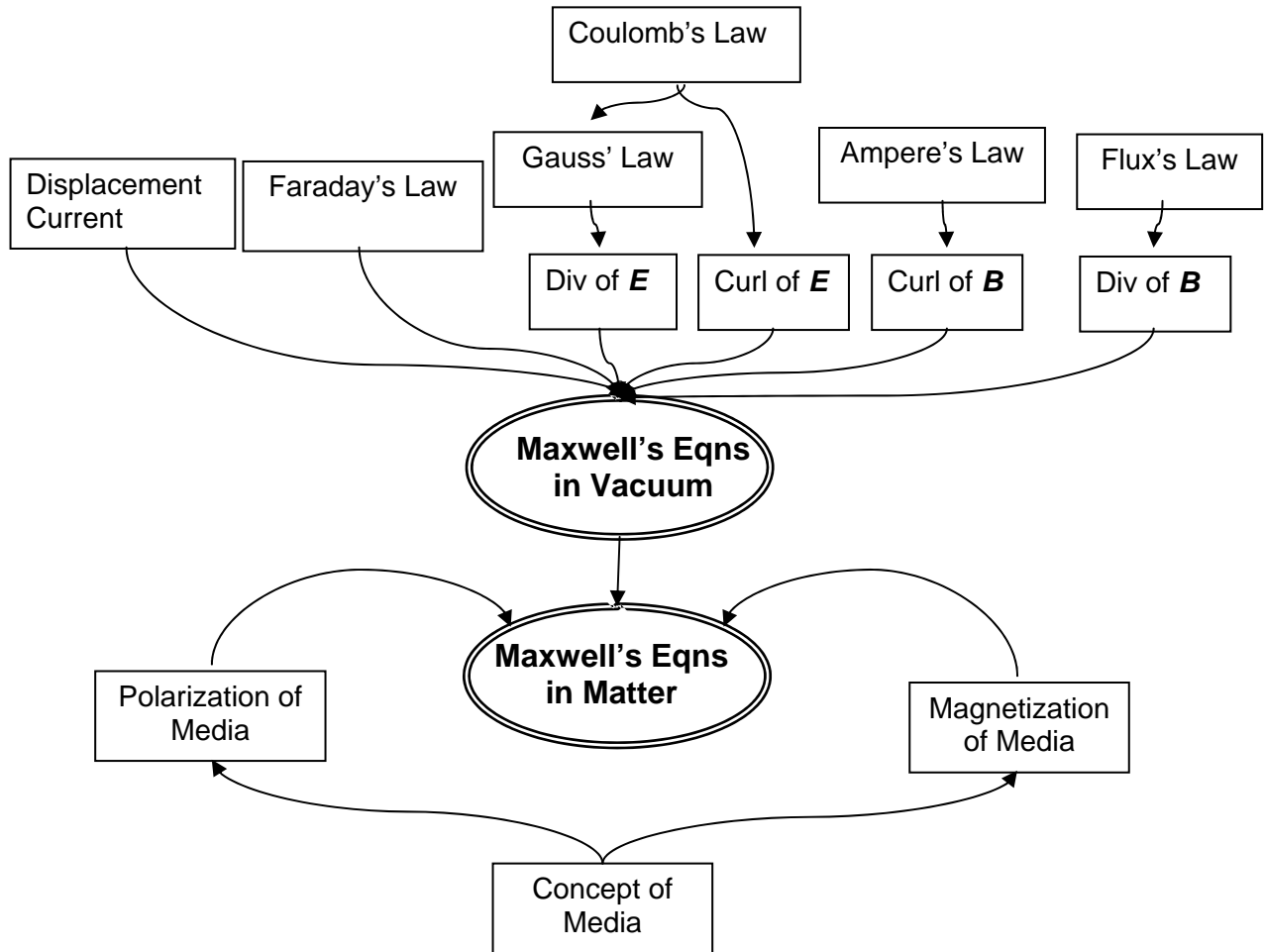


Figure 4. Concept map of Maxwell's Equations

Chapter 3. Solutions of Static Electromagnetic Equations

Content

- 3.1 Electrostatics
 - 3.1.1 Electric Potential
 - 3.1.2 Electrostatic Boundary Conditions
 - 3.1.3 Laplace's Equation
 - 3.1.4 Uniqueness Theorem
 - 3.1.5 Separation of Variables
- 3.2 Methods of Imaging
- 3.3 Magnetostatics
 - 3.3.1 The Vector Potential
 - 3.3.2 The Scalar Potential
 - 3.3.3 Magnetostatic Boundary Conditions

Strategies

1. Problem-solving skills. In this chapter, there are many problems and the problem-solving skills of the students will be well trained.

2. Teamwork. In order to develop the spirit of cooperation, I will ask the students to form small groups to finish their assignments.
3. Summary. In order to let the students develop deeper understanding, I will ask them to compare the formulas of E and B fields.

Chapter 4. Electromagnetic Waves and Their Applications
Content

- 4.1 Plane Electromagnetic Waves
- 4.2 Reflection and Refraction of Electromagnetic Waves at a Plane Interface between Dielectrics
- 4.3 Electromagnetic Waves at the surface of and within a Conductor
- 4.4 Wave Guides
- 4.5 Resonant Cavities

Strategies

1. Problem solving skills. There are also many problems in this chapter.
2. PBL. The problem is 'as a metal object, how does the Stealth Fighter avoid being detected by Radar?' It is based on the theory of EM waves interacting with conductors. In this strategy, many skills, such as independent learning, library-based learning, web-based learning, will be developed. At the end, I will ask the students to give mini-presentations so that the students' oral communication skills will improved.

Chapter 5. Special Relativity

Content

- 5.1 Background (History and experiments)
- 5.2 Einstein's Two Postulates
- 5.3 The Geometry of Relativity
- 5.4 Lorentz Transformations
- 5.5 Relativistic Mechanics
- 5.6 Relativistic Electrodynamics

Strategies

1. Case study. I will tell the students the history of Special Relativity's development and some stories about famous physicists and great events, to excite their interest and teach them how to think critically and creatively.
2. Concept changing. I will help the students to gradually change their old concepts of space and time to new ones.
3. Web and library-based learning. I will ask the students to observe a demonstration on <http://www.anu.edu.au/Physics/Searle/> to help their understanding.

Discussion

Further research on teaching and learning methods is needed.

After 3 months' study, I think that different teaching and learning theories, strategies, approaches and concepts have common ground and relationship, therefore they need to be compared, concluded, systematised and unified.

Having teaching and learning methods is not equal to having a high quality of teaching and learning. It involves the other factors of teachers, students and society. We need to extend our research deeper and wider.

There are a number of great educators in Chinese history, and even at the beginning of the 20th century, there were

many great educators in China. They understood Chinese and Western cultures very well and also had great ideas. Comparative research on education methods between eastern and western cultures is needed.

Conclusion

With the development of our economic reform, the higher education system of our country is facing a great change. Contemporary teaching and learning methods will be of great benefit to our higher education system. I believe that the quality of teaching and learning in my course, *Classical Electrodynamics*, will be greatly improved by using student-centred teaching and learning strategies.

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