Consideration and Practices in Academic Talents Oriented Research Type Teaching in <<Electromagnetics Theory>>

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Abstract. With the popularization of higher education, colleges and universities in China carry the responsibility of bringing up diverse type of talents. A teaching practice aiming at educating academic talents is introduced in this paper. This teaching practice targets at delivering knowledge as well as training the students’ abilities. Based on this target, the consideration in selecting the teaching contents, and practices in the research type teaching are reported. Examples of learning outcome from students are presented, and the challenges and corresponding treatment are discussed.

Introduction

Recently, with the development of the education idea and web-based techniques, novel educational methods and skills keep emerging. This results in educational reformation in universities and colleges [1], [2]. New modes in education in universities are going through discussion and practice [3], [4]. However, various modes still serve the same essential of education that will not change. That is, education is always student oriented. Due to the popularization of higher education in China, there is practical necessity of develop pluralistic objects of the higher education. Despite this fact, some common characteristics in the university graduates are called by our country, which is in the accelerated process of development towards innovated nation. Accordingly, we need to develop the following abilities in our students, i.e., the sense of innovation, the sense of independence, the ability to innovate, and the ability to adapt to the society. That is right what our famous scholar and educator Guowei Wang said, “Independence in spirit, and the freedom in will.” According to the pluralistic objects of the higher education, the university where the authors work customized a specialized education module of “Bachelor-Doctor” for selected students showing talents and capability in doing research. The objective for this system is to foster academic outstanding researchers.

In this paper, the ideas in designing and the measures in teaching the “Bachelor-Doctor” course <<Theory of Electromagnetics>> is introduced. According to the academic foundations and the ability of the “Bachelor-Doctor” students, the teaching objectives for this course is not only to teach the basic knowledge, but also to train the ability required in academic research. At the same time, we also pay great attention to providing a broad view of the academic field. The teaching contents is carefully tailored to provide both classic theories, and state-of-art techniques. On the class, the independency of thinking from the students is greatly appreciated. The teacher plays the role of guiding the students during the process of exploring in the field, instead of passing knowledge and teaching methods. In order to do that, the teacher selected several questions to be discussed on class with the students. Through the study of these questions, the students get more motivated in studying the course because of aroused interest in the field. Their ability of utilizing the knowledge to solve problems are trained. Their ability of doing research, such as doing literature review, to follow the logics in academic papers, and to think critically is trained. These are the fundamental merits in creative thinking and doing research. Our practicing, designing philosophy, consideration and the enlightenment gained during the teaching process are presented in detail below.
The Practicing and the Designing Philosophy for the Research-oriented Teaching

● The Thinking in The Teaching Objectives

<< Theory of Electromagnetics >> is the basic course in Electronic Engineering or Telecommunication Engineering in national range. This course forms the foundations for many specialized subjects. It also connects to basic physics which makes it a very important understructure and growing point for various developing scientific subjects. In this course, the electromagnetic properties and laws are studied in the perspective of electric and magnetic fields. One can see from this course how mathematics serves in the progressing of physics and how physics motivates the development of mathematics. With a complete logic structure and the self-consistent subject system, this course shows an impressive typical characteristics of the close combination of mathematics and physics. As a consequence, this course is desirable for training the logic thinking of the student, as well as fostering the mentality of utilizing the mathematic ability to solve practical problems in the physical world. With the development of hundreds of years, there are rich knowledge accumulated in this field and lots of skills and techniques are developed which forms one of the most important foundations for this information era.

A traditional teaching objective of the << Theory of Electromagnetics >> course is to communicate the rich classical knowledge and pass on the classical skills for solving the EM problems. However, the educational target for the “Bachelor-Doctor” module is to foster academic outstanding researchers. Aiming at this target, the basic knowledge are important but far from sufficient. A lot of abilities, as well as some merits are necessary. These abilities include the ability of mathematic derivation (related to mathematic foundation and strong logic flow in the mind), the ability of understanding (reading information) from mathematic equations, the ability of synthesizing, integration of knowledge learned and make judgments, the ability of connecting and utilizing knowledge learned to solve new problems, the ability of searching papers and doing literature review, the ability of self-studying, the abilities of thinking independently and critically (being able to challenge experts), the ability to make plan and for time-control, etc. Last but not the least, one potential scholar’s academic career also directly related on the following characteristics in the person, the curiosity in the world, the willingness and eagerness in learning, and the passion for creation.

According to the above analysis, we focus our teaching objectives to teaching the basic knowledge, as well as training the ability required in academic research. Targeting at this, conventional teaching contents are tailored, topic-based discussion is introduced to the conventional class, and the teaching and learning process is guided the studies of specific well selected problems.

● The Tailoring of the Teaching Contents

As a matter of fact, development of technology and development in academia has greatly changed the way of teaching and learning. Firstly, thanks to the rapidly developing web-based technology, development of web-paged information sources based on searching engine, such as the Wikipedia, the googles, and the baidu, together with the development of the Massive Open Online Course (MOOC) [5], [6], the micro-course, and the flipped class [7], has made various types of open sources for knowledge available to public, including students on campus. Many Libraries have been digitalized as well. As a matter of fact, the access of knowledge becomes more convenient than ever. However, the web-based open source lacks of integration in a systematic way and cannot simply suit anybody. Secondly, knowledge itself is experiencing evolution. New concepts, new phenomenon and new skills are emerging in an accelerating way. On the other hand, some knowledge and skills which once was hot problems in the history, may not be of great interest today anymore. Therefore, there must be a trade-off between the classical knowledge system and the newly developed knowledge. It’s the teacher’s responsibility to organize the contents of teaching and balance the details that arranged to one certain point.
Since the students of the “Bachelor-Doctor” module are selected to have stronger learning ability and stronger logic thinking ability, there are chance for them to access some of the state-of-art techniques in electromagnetics.

So the teaching contents for this module include some interesting academic topics with medium challenges. Due to the adding of researching topic, the time for independent thinking discussion need to be increased accordingly, hence the compression of classic knowledge is necessary if we do not change the total class hours. One key point is to select the teaching contents, including the compression of the classic knowledge system, and the selection of interesting academic topics.

In the compression of the classic knowledge system, the standard for our choice is to reserve the completeness and the essentials of EM theory. On this aspect, we select the book <<Essentials of Electromagnetic Wave Theory>> as our text book [8]. In this book, the classic EM theory and corresponding methods for the static fields is not presented. Instead, the classic EM theory and corresponding methods for the EM waves are discussed based on classic problems, including the wave propagation and transmission, the radiation and the scattering. In this way, a complete solution of a typical information system is discussed and presented, which closely relates to our information society. Throughout the book, the concept of the “field” is always the core of the problems. Through the solving progress for the fields, one can clearly see how the strong logic system in mathematics can push forward the progress of physical concept, and how the physical insights are clearly explained in a mathematical way. Due to the above reasons, this textbook is suitable for potential academic researchers. Experience of four years usage also validate that this text book suits the major of Electronic Engineering and can provide a strong support for the subsequent specialized courses in this major. We also use the book “Electromagnetic field and electromagnetic waves” by David. Cheng [9] as a reference book for the rich details of terms, derivation and examples.

The selection of the state-of-art academic hot topics relates closely to the authors’ own research interest. For example, the transformation-based optics proposed by Prof. John Pendry in 2006 is one of the candidate topics. In one paper published in the “Science” magazine, Prof. Pendry demonstrated how to guide the EM waves by designing materials based on transformation between different coordinate system. Based on this theory, many fancy electromagnetic devices can be designed. Because of that, this transformation optics was chosen as the research topic for the mini project of the “Bachelor-Doctor” module. On the class, the students were encouraged to study the related academic paper, to follow the derivation of equations through discussions. Off the class, they spent weeks to understand the whole theory and designed their own EM devices, with simulations run as verification of their design. Following papers [10]-[15], EM cloak, EM wave beam amplifier, wave beam concentrator, and EM rotator were successfully designed and verified by all the students. Figure 1 shows the EM simulation results of the EM wave beam amplifier, and the EM cloak of arbitrary shape. Figure 2 shows the EM simulation results of the EM wave rotator. Through the process of solving this problem of this mini-project, the students practiced reading academic papers. Their ability of mathematical derivation is trained. Their abilities of transforming mathematic equations to EM device designs are trained and they learned how to use the commercial software to verify their idea. More to the point, through this example project, they get access to the process of doing scientific research. They practiced thinking independently, and practiced discussion with their peers. Last but not the least, the students get access to “live” problems, through which they experience by themselves the power of mathematic derivation and get more interested in the science of electromagnetic theory.

- The Feedbacks and Deficiency

At the end of the course module, the teacher collected the feedbacks from the students through a survey. Several enlightening points were shown from the survey. First, the students were happy with the cutting out of the classic teaching content of static fields. Since these students are in the “Bachelor-Doctor” module, they do not need to sit the entrance examination for postgraduate module, in which content of static fields will be examined. So they are happy with the “burden” of “static field” released. Secondly, they were interested in the research topic and enjoy the process of
doing scientific research though it was hard. They felt the hardness because, on one hand, the theory was new and the problem itself was more challenging than classical problems on conventional textbooks. On the other hand, listening to the teacher’s explicit teaching on class, which they were used to from primary school, is apparently much more easier compared with practicing self-learning and peer-learning through discussion with classmates. However, they were able to experience the excitement and confidence when they accomplished this challenging task through their hard work. This hardship and effort became a valuable wealth for their future study. Thirdly, some students gave the feedback that the efficiency of the acquirement of knowledge on the research-typed teaching class is lower than that on a conventional explicit teaching class. The author are aware that this is unavoidably true, since fraction of class hour need to be spent on the training of necessary ability. And that is right the reason the teacher need to cut-out some classical knowledge points. The authors are also aware that the students at the Bachelor stage are thirsty for input of wide knowledge. In order to meet the demand on wide knowledge from the students, the authors wrote a new book with more physical concepts, more terms, more techniques, explanations and examples as text book for this module. More add-ons, such as micro-courses on website is also in-developing to provide more knowledge for these students as supplementary studying materials. Flexible course styles such as MOOC, flipped classes could also be introduced in the future courses to increase the efficiency of the teaching and learning process.

Figure 1. The EM simulation results of (a) the EM wave beam amplifier, and (b) the EM cloak of arbitrary shape.

Figure 2. The EM simulation results of the EM wave rotators.
Summary
In this paper, the consideration and practices in designing the course "Electromagnetics Theory" is presented. Based on the education target of the specialized education module of “Bachelor-Doctor” in the authors’ university, which is to foster potential academic talents, research type teaching is adopted. The abilities required for academic study is analyzed. The strategy for tailoring the teaching contents are explained and one research topic are presented as an example to demonstrate how these mini-projects can be of help in training the abilities of the students. The examination is made by the teachers from the class behavior of the students. The feedbacks from the students are also analyzed in depth. Future work to improve the attempts towards research typed teaching is suggested.

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