Photonics Education Development for Electrical Engineering Students

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ABSTRACT

We describe the contents of an advanced undergraduate course on photonics at School of Electrical Engineering, Chongqing University of Posts and Telecommunications. The main goal of the course is to equip the student with the necessary theoretical and practical knowledge to participate in photonics-related industry and further graduate level study and research if they choose. The prerequisites include college-level physics and higher mathematics which a general engineering student has already had in his/her first and second year college study. Although applications of photonics are ubiquitous such as telecommunications, photonic computing, spectroscopy, military technology, and biophotonics etc. Telecommunication information system application is more emphasized in our course considering about the potential job chances for our students.

Keywords: Photonics Education, output based education (OBE), curriculum, engineering education accreditation

1. INTRODUCTION

The field of photonics, sometimes referred to as optoelectronics[1], has continued to evolve since the invention of the laser in 1960, it is the physical science of light (photon) generation, transmission, modulation, amplification and detection etc.[2]. It has found ever-increasing applications in optical communications, computing, sensing, display, printing, and biomedical imaging etc. In order to make students have enough knowledge and abilities for photonics-related industry and further graduate level study and research, several middle-to-advanced level undergraduate courses related to photonics have been taught to students at School of Electrical Engineering, Chongqing University of Posts and Telecommunications (CQUPT) for the past more than ten years. Although the contents of the courses are constantly updated to keep abreast of the latest technological and product developments in the field, due to the dynamic nature of photonics industry and academia, how to adjust photonics teaching and training methodology such as curriculum design, class instruction and students examination has always been a big challenge.

As a teaching and research institution with traditional excellence in the area of information and communication technology, Chongqing University of Posts and Telecommunications(CQUPT) has always committed to providing its science and engineering students with well-prepared professional education and training for their future career development in China since its establishment in 1950. With the advent of the new century, on the background of economy globalization and educational internationalization, CQUPT, like many other Chinese universities, has also been making education innovations to face the issue of training the engineering students with international perspective. About several years ago, majorities of undergraduate engineering programs from CQUPT begun to follow the Chinese Engineering Education Accreditation Criteria (CEEAC) for the program development. In fact, several programs have already been actively in the process of getting program accreditation. As China, represented by the Chinese Engineering Education Accreditation Association became full signatory of the Washington accord [3-4] last year, CQUPT is even more motivated to seek accreditation of its engineering programs to demonstrate that its programs meet the demand of educational internationalization.

Presently, the school of electrical engineering from CQUPT includes four undergraduate programs with specialties in optoelectronic information science and engineering, electronic science and technology, electronic information engineering & electromagnetic field and wireless technology. According to 2015 CEEAC, the basic knowledge on physical optics, applied optics, optoelectronic technology and optoelectronic detection technology are required for the program of optoelectronic information science and engineering. And for the program of electronic science and technology, the basic knowledge on at least three of eight subjects listed in 2015 CEEAC are required, and these eight subjects are solid state physics and semiconductor physics, microelectronic devices and technology, integrated circuit principles and design, electronic design automation, optoelectronic devices and technology, microwave and optical

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waveguide technology, laser principles, and electronic material and elements. In order to satisfy the requirements of CEEAC, one course called ‘Optoelectronic Technology and its Applications’ has been redesigned and taught to third-year undergraduate students from both optoelectronic science and engineering & electronic science and technology programs. This paper presents various aspects related to this course such as its acting role in the program curriculum system, topics covered, teaching methods and assessment etc.

2. DESCRIPTION OF THE COURSE

2.1 Curriculum design at School of Electrical Engineering

Although the traditional education approach at school of Electrical Engineering from CQUPT was mainly on input-based methodology, which means the curriculum, course syllabus, and student performance assessment were mainly designed based on the idea of instructor-centered knowledge-input without enough concern of the final education outcomes, i.e. the survival capabilities of the students in their future career development, however, output based education (OBE) has been gradually adopted in recent years in order to face the drastic changing social environment and satisfy the CEEAC concurrently. Figure 1 outlines the general OBE design process for each program at school of Electrical Engineering from CQUPT.

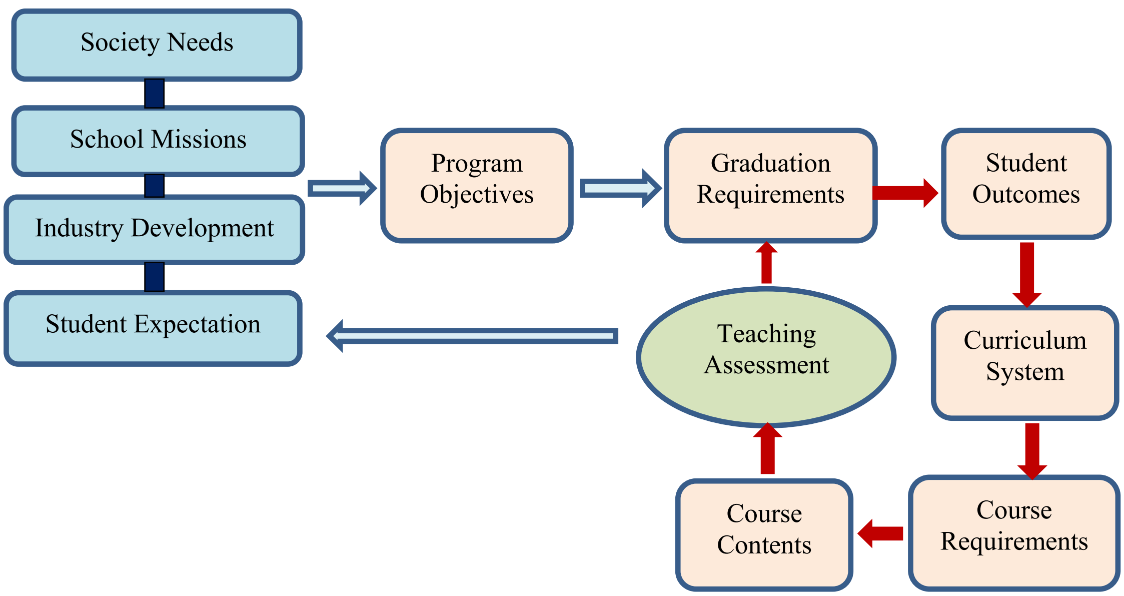

Figure 1. Output-based education design process at School of Electrical Engineering from CQUPT.

In Figure 1, program objectives concern what the students can do after their graduation by considering all those important factors such as social needs, industrial development prospects, school development missions, and the expectations from students and their families, graduation requirements concern what the students should have when they graduate, which are specified by student outcomes in a detail list, and based on student outcomes, the curriculum system and course syllabuses are designed. In order to show the correlative relationship between the student outcomes and curriculum system in a systematic and clear way, a format like Table 1 called outcome realization matrix is used for curriculum design. Through this output-based education design process, the program objective of Optoelectronic Information Science and Engineering at School of Electrical Engineering is first set to train students with R&D and engineering management abilities in the fields of optoelectronic information and electronic information, and then, five student outcomes are identified as follows:

Outcome1: The broad education necessary to understand the impact of engineering solutions in a global, economic, environmental, and societal context, an understanding of professional and ethical responsibility, a knowledge of contemporary issues.

Outcome2: Personal comprehensive capabilities such as scientific writing, interpersonal communication and creative thinking etc..

Outcome3： Abilities to apply knowledge of mathematics, physical science, computer programing and foreign language.

Outcome4: Mastering fundamental theories, basic knowledge and professional skills in the fields of optoelectronic information and electronic information.

Outcome5: Abilities to use the techniques, skills, and modern engineering tools necessary for engineering practice in the fields of optoelectronic information and electronic information.

For each category of outcome, several subcategories are also specified which are not listed here in details for simplification. For each course in curriculum system, the correlated relationships with the outcomes are represented by the check marks in the realization matrix as shown in Table 1. From Table 1, it can tell that the course of Optoelectronic Technology and its application is correlated with outcome 4, which means that this course is designed for helping students to master fundamental theory and knowledge in photonics, and also to understand its major applications. Many other courses in the curriculum of the program are not listed here for simplification purpose.

Table 1. Output realization matrix for education program design of optoelectronic information science and engineering.

Courses	**Outcome1**		**Outcome2**		**Outcome3**		**Outcome4**		**Outcome5**	
	1.1	1.2	2.1	…	3.1	...	4.1	...	5.1	...
Ethics and Law	✓	✓								
Contemporary Issues and Policies	✓	✓								
College English	✓	✓				✓				
Higher Mathematics					✓					
College Physics					✓					
Optoelectronic Technology and its Applications								✓		
Comprehensive photonics project								✓	✓	✓
Other courses …										
Graduation project								✓	✓	✓

2.2 Topics covered in the course of Optoelectronic Technology and its Applications

The course of Optoelectronic Technology and its Applications is designed as a one-semester 48-credit-hour required course for junior students from both programs of Optoelectronic Science and Engineering & Electronic Science and Technology at School of Electrical Engineering. In the syllabus of this course, it is first described as follows: "By combining the research methods from both photonics and electronics, it studies the technology for generation， transmission， processing and detection of optical signals. We will focus on basic concepts, principles and applications of those major components for information generation, propagation and processing of optoelectronic information systems especially optical communication systems. Specifically, the class will cover the fundamental concepts and principles of optics, laser principle and technology, optical wave guiding, optical modulation, optoelectronic detection technology and applications." After this brief introduction, the targets of this course are specified as follows:

Target 1: Understand the physical concepts of interference, diffraction and polarization, basic electromagnetic theories and mathematical representation of optical wave, derive optical wave equations in simple dielectric medium, and calculate the optical reflection, transmission and absorption in simple medium.
Target 2: Develop system-level knowledge & concept, such as signal generation, modulation, propagation and receiving of optoelectronic information system, to solve real engineering problems.
Target 3: Develop device-level knowledge & concept, such as light sources, optical modulators, optical waveguides, optical detectors, and optical displays etc., to solve real engineering problems.
Target 4: Have knowledge of photonics development history, current issues and future trends, apply theoretical knowledge learned in this course to analyze and solve problems, dare to be first and win through innovation.

In order to show the correlation of the specific topics covered in the class and the course targets, a correlation matrix like Table 2 is used, from this table, it can tell that output based education concept has been applied here again. Due to limited space in Table 2, not every detail is listed, however, five major topics in this course can still be identified in this table, which are as follows: fundamental knowledge of optics, laser principles and technology, waveguide technology, optical modulation and detection technology. There are only three teaching methods listed here, of course, they are flexible and adjustable based on the specific situations of the class.

Table 2. Relationship between class topics and the course targets

Order	Topics	Teaching Requirements	Class Hours	Teaching Methods	Course Targets
1	Introduction of optoelectronic technology	1) Knowledge of optoelectronic development history 2) Understanding information transmitting process of an optoelectronic information system and the corresponding functional components 3) Knowledge of major applications of optoelectronic technology	2	Content explanation, Heuristic questions, Case analysis	Target2, Target4
2	Fundamental knowledge of optics and light propagation law	1) Understanding wave-particle duality nature of light 2) Understanding reflection, transmission laws and total reflection, independent propagation principle of light 3) Understanding polarization and its mathematical processing	2	Content explanation, Case analysis	Target1
…	…	…	…	…	…
7	Laser principles and technology	1) Understanding the concepts of coherent and incoherent light sources 2) Derivation of dielectric susceptibility coefficient 3) Understanding physical meanings of the real part and the imaginary part of the complex susceptibility, concepts of normal dispersion region and anomalous dispersion region	…	…	Target2, Target3
…	…	…	…	…	…
14	Fundamentals of waveguiding technology	1) Understanding the functions and classification of optical dielectric waveguides. 2) Knowledge of optical fiber development history 3) Understanding forming mechanism and propagation properties of guide waves and evanescent waves in optical dielectric slab waveguide	2	Content explanation, Heuristic questions, Case analysis	Target2, Target3
…	…	…	…	…	…
17	Optical modulation	…	…	…	…
…	…	…	…	…	…
21	Optical detection	…	…	…	…
…	…	…	…	…	…
24	Final Course Review	1) Understanding interrelations of class materials covered in the whole semester 2) Understanding all the targets of the class	2		

3. COURSE ASSESSMENT

3.1 Course target evaluation methodology

The course target evaluation methodology also follows the idea of OBE, which is shown by Table 3. Of course, a lot of details are not listed here due to the limited space here.

Table 3. Relationship between the course targets and student performance evaluations

Course Targets	**Knowledge and abilities to be evaluated**	**Evaluation methods**
Target 1: Understand the physical concepts of interference, diffraction and polarization…	Knowledge： 1) Wave-particle duality of light 2) Reflection, transmission, total reflection, independent propagation principle of light 3) Interference, diffraction and polarization … Abilities： Derivation of light wave propagation equations in simple dielectric medium from Maxwell equations, Calculation of light reflection, transmission and absorption in simple dielectric medium	1) Homework (15%) 2) Attendance (15%) 3) Quizzes (20%) 4) Final Exam (50%)
Target 2: Develop system-level knowledge & concept …	. . .	. . .
Target 3: Develop device-level knowledge & concept …	. . .	. . .
Target 4: Have knowledge on photonics development history …	. . .	1) Homework (including subject report) (15%) 2) Attendance (15%) 3) Final Exam (50%)

Traditionally, the final exam accounted for 70% of the course grade, it is adjusted to 50% in order to make students focus more attention on regular study process rather than only do intensive memorization for final exam. Several class quizzes accounting for 20% of the total grade are given during the semester to stimulate students to learn on regular basis and develop more effective study habits. Student attendance is set to 15% for encouraging them to be actively involved with the professor lectures, and to develop a good habit of discipline by following the regular class routine. Homework still accounts for 15% as usual, but, in contrary to assignment only taken from the problem sets in the text book, writing a scientific paper, making a class presentation, or getting an engineering project done by using modern scientific research tools such as internet, computer programming or professional simulation software are encouraged. And all those class assessment modifications are for the purpose of training the students more capable to deal with the real society rather than simply appear good in their final exam, and also more likely to fulfill the requirements from the Engineering Education Accreditation Criteria. Finally, at the conclusion of the course, performance (average final score of the whole class) ratings for the course targets are shown in Table 4.

Table 4. Performance ratings for the course targets

Performance (Average Score)	Rating
90-100	Excellent
80-89	Very Good
70-79	Good
60-69	Poor
<60	Unacceptable

3.2 Course assessment survey questionnaire to students

At the end of the semester, before the final exam, the students are also required to answer an online assessment survey about the course. Presently, there are six evaluation items listed in the assessment survey as follows:

1. Instructor's teaching style
2. Instructor's teaching attitude
3. Instructor's teaching ability
4. Instructor's teaching methods
5. Effectiveness of teaching
6. Overall satisfaction degree of teaching

Each item is rated on four-point scale as A, B, C, and D, and the final evaluation results of the course are calculated based on this online survey.

4. CONCLUSIONS

A course titled as Optoelectronic Technology and its Applications has been described. The course is targeted at the third year undergraduate electrical engineering students from Chongqing University of Posts and Telecommunications for their photonics education. The class material mainly covers the contents of laser principle and technology, optical waveguide theories and technology, optical modulation and detection. In recent several years, the program curriculum, course syllabus and assessment have been redesigned based on output based education (OBE) concept to face the never-ending changes of the society and to prepare for getting the engineering program accreditation from Chinese Engineering Education Accreditation Association. The course assessment results show that although the new approaches make the students' average performance ratings relatively lower than traditional methods, the overall satisfaction degree from the students are improved, which means that this type of education renovation is in general more helpful for students' learning. Of course, a lot of improvements are still needed to fulfill the final goal of helping students have a more successful career and social life in their future, the present teaching renovations can be thought on the positive side of achieving the final goal.

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