Using CDIO to Design a Career-Oriented Electrical Engineering Curriculum for Regional Universities of China

Lin Cui, Fei Gao, Jianpei Chen, and Lingling Kong

***Abstract*—In China, some traditional Electrical Engineering curriculum are designed based on the knowledge structure of discipline and lack of practice, which cause the graduates hard to fully meet the requirement of applied and compound talents. So Ministry of Education has put forward the strategy of transition for some regional universities. Curriculum reform is one of the key reforms. Considering the knowledge and the comprehensive abilities needed for career, this paper presents a double closed-loop model for curriculum design. Taking the career of 418 graduates as a sample, it designs a two-dimensional curriculum with the career-oriented outer loop. The horizontal axis is three modules according to the career classification, and the vertical axes respectively follow the progressive relationship of the theoretical knowledge and engineering practice. It contains professional module courses, project design courses, career guidance courses, and so on. In the CDIO-oriented inner loop, student outcomes are assessed in order to adjust the curriculum. CDIO Syllabus and ITU skills are integrated into the curriculum, which enhances the achievement of student outcomes.**

***Index Terms*—Curriculum, career-oriented, CDIO, electrical engineering (EE), student outcomes.**

I. Introduction

In order to adapt to economic development and solve the contradiction between industrial restructuring and the shortage of applied talents, China's Ministry of Education has put forward to intensify the reforms of personal training and curriculum with demand-oriented in "Guidance on Some Regional Colleges and Universities to Transition to Applied Education" [1]. The transition from academic education to applied education can increase the role of regional colleges and universities in promoting and serving regional economic development. Granted, the traditional academic graduates are difficult to fully meet the requirement of applied and compound talents. According to the feedback from engineering graduates, academic education has less impetus for professional ability and career development, which is mainly reflected in its curriculum: 1) Theory courses mostly focus on the knowledge structure and have little contact with engineering practice; 2) Experimental courses are largely comprised of single verification experiments, lack of comprehensive experiments; 3) The gap between traditional experiment and modern production is relatively large [2], [3]. Therefore, it is very urgent to reform the curriculum.

Domestic universities have made a great deal of attempts in curriculum reform and have scored great achievements. Nanjing University of Aeronautics and Astronautics puts forward the courses group to optimize overlapping contents and integrate isolated contents in the related courses, so as to enable students to acquire knowledge and skills in the shortest time [4]. The General Standard for Chinese Engineering Education Certification stipulates that curriculum design needs the participation of industry professionals or academic experts [5]. Wuhan University accepts the suggestion from industry professionals and adds a new course "Electrical Equipment Monitoring and Fault Diagnosis Technology", which fill the gap in the smart grid for students [6]. With the internationalization of engineering education in China, Shantou University adds multi-level project-driven design courses into their curriculum based on CDIO idea, which inspires and guides students to self-study, and improves their ability by comprehensive experiments [7]. In addition, some universities carry out school-enterprise cooperation [8], [9]. Coming into classrooms as teachers, industry experts strengthen the connection between knowledge and engineering practice. Coming into enterprises for visiting or internship, students get more perceptual knowledge.

However, among the above reform measures, the former two are based on the structure of knowledge, and the latter two are based on the improvement of engineering practice. Currently there have been no curriculum that aims at the career demand knowledge and comprehensive ability together. Therefore, this paper uses CDIO to design a career-oriented Electrical Engineering (EE) curriculum that is specific to regional universities in China.

II. Design Model of Curriculum

First of all, curriculum design needs idea to support. In 1994, Outcome-based Education (OBE) proposed by Spady [10] has become the mainstream idea of education reform in the United States, Britain and Canada. Accreditation Board for Engineering and Technology (ABET) spreads it throughout the engineering education accreditation criteria and assesses student outcomes. Specially, it is mentioned that the curriculum does not prescribe specific courses [11]. In 2000, experts from four universities including MIT inherited OBE, then presented CDIO Initiative which integrates the engineering fundamentals of conceiving-designing-implementing-operating (C-D-I-O) real world systems and products into curriculum [12]. An engineering introductory

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course inspires students' interest and motivation in engineering application [13], [14]. Comprehensive learning and engineering practice reinforce the student outcomes [14]. Above three features ensure an engineering curriculum more practical and acceptable. Moreover, student outcomes followed such curriculum meet the new demand of talents. The product, process, and system building skills in the fourth section of CDIO Syllabus are consistent with the demand of applied talents. The personal and interpersonal skills in the second and third section of CDIO Syllabus are consistent with the demand of compound talents. Therefore, it is more appropriate to use CDIO Initiative to guide curriculum design.

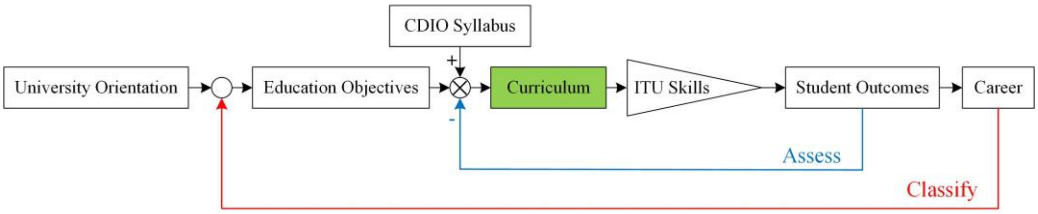

Fig. 1. Curriculum design model.

Secondly, curriculum design is based on the university's educational objectives. The General Standard for Chinese Engineering Education Certification notes that educational objectives must be consistent with university orientation and meet needs of social and economic development [5]. In China, there are 444 universities offering major in EE [15]. EE covers five sub-categories that Electric Machinery and Electric Equipment, Power System and Automation, High Voltage and Electrical Insulation, Power Electronics and Power Transmission, Electrical Theory and New Technology. Each sub-category corresponds to different courses and employment fields. However, some regional universities are unable to offer courses in every sub-category due to their incomplete disciplinary structure and weak teacher resource. And with poor quality of students, these universities' orientation and students' job-hunting are attacked from both higher level universities and vocational colleges. Hence, the regional universities could design career-oriented curriculum which contains module courses for local career classification, practice courses for improving career ability, and guidance courses for personal career planning.

Thirdly, curriculum design should support student outcomes. Teachers integrate CDIO Syllabus into specific course, and promote student outcomes through Introduce-Teach-Utilize (ITU) skills [16]. Course contents and teaching methods are continually improved according to student outcomes assessment.

Above all, this paper presents a curriculum design model as shown in Fig. 1. In line with university orientation, education objectives are built according to career classification. On the basis of education objectives, CDIO Syllabus and feedback from student outcomes assessment, curriculum is designed and implemented with ITU skills to enhance student outcomes. This model includes a career-oriented outer loop and an CDIO-oriented inner loop. Among the outer loop, the design of professional module courses, project design courses and career guidance courses are given. Among the inner loop, the examples of integrating CDIO Syllabus into curriculum and using ITU skills are given.

III. CAREER-ORIENTED OUTER LOOP

In this paper, a university of Yunnan Province in China is as example, whose distribution of 418 graduates during 2013 to 2017 as shown in Fig. 2. Apart from institutional organization and services industry which are less related to EE, graduates have mostly classified in three domains that power generation, power transmission and power supporting industries. It should be noted that power supporting industries in this paper include industries about automation operation, equipment manufacturing and power construction.

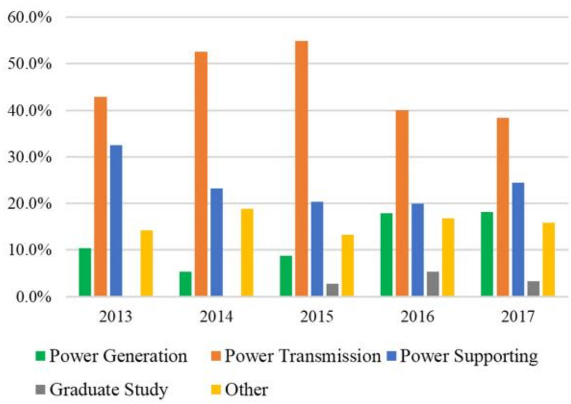

Fig. 2. Distribution of EE graduates of a university in Yunnan during 2013 to 2017.

Two-dimensional curriculum shown in Fig. 3. The horizontal axis is three modules according to the career classification, and the vertical axes respectively follow the progressive relationship of the theoretical knowledge and engineering practice. Part of courses for different modules are different. So math and science courses, basic engineering courses and basic professional courses are supplied uniformly, professional module courses corresponding to three domains are electives. The courses and project designs (PD) at different levels are progressive and mutually supportive.

Math and science courses contain 11 courses with a total of 27 credits. They are offered in 1st-3rd semester, which provide necessary basic knowledge, analysis methods and calculation methods for the following courses.

Basic engineering courses contain 11 courses or labs with a total of 25 credits. They are offered in 2nd-4th semester. In 3rd semester, "Introduction to Electrical Engineering" introduces the composition of power system, supporting technology, follow-up courses, and employment domains. Let students know what is the major for and what they want to be, so as to choose the appropriate professional module courses later. It has to be emphasized that this course is very necessary, and the engineering introductory course is one of innovations in CDIO. Other basic engineering courses play an important role in guiding students from the field of mathematics to the field of engineering.

Basic professional courses contain 15 courses or labs with a total of 32 credits. They are offered in 4th-6th semester. As the knowledge base for three career domains, these courses provide students the professional principles and knowledge to analyze and solve the electrical engineering problems.

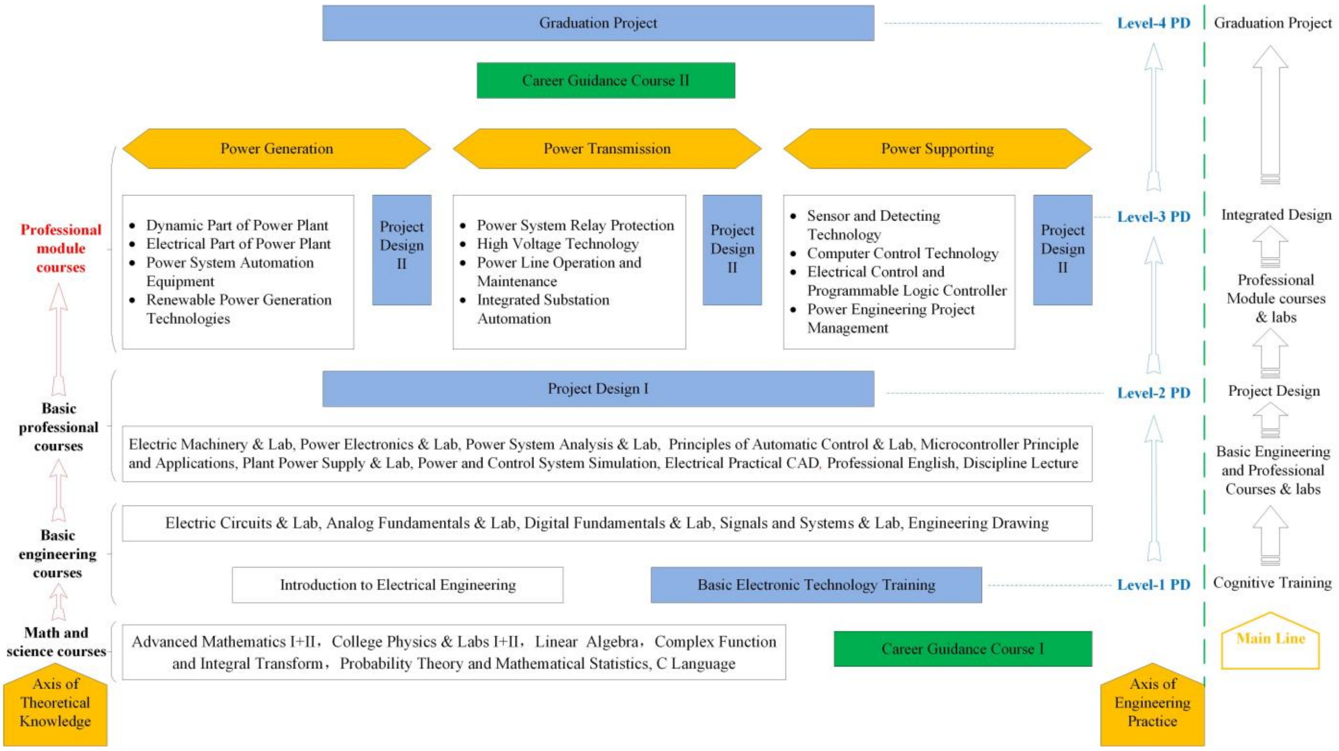

Fig. 3. Two-dimensional EE curriculum.

A. *Professional Module Courses*

The design of professional module courses is to strengthen the connection between theoretical knowledge and career. According to the classification of career, we respectively set up professional module courses for power generation, power transmission and power supporting industries. Students choose two modules in 6th-7th semester.

1) *Power generation:* Among those graduates worked in power plants, the percentages of hydroelectric plant and new energy power plant both account for 38.1%, which is related to hydropower's and solar energy's dominant status in Yunnan. The main duty in power plants involves the operation, maintenance and monitoring of dynamic equipment and electrical equipment. So, four courses, "Dynamic Part of Power Plant", "Electrical Part of Power Plant", "Power System Automation Equipment" and "Renewable Power Generation Technologies", are offered. The main contents and the opening semester are showed in Table I.

TABLE I: FOUR COURSES IN POWER GENERATION

Course	Main content	Term
Dynamic Part of Power Plant	thermodynamic principle and steam turbine operation (brief), hydromechanics and water turbine operation, wind measurement and wind turbine operation (particular), etc.	6
Electrical Part of Power Plant	substation types, electrical wiring and design of plant, reliability analysis of electrical equipment and main wiring, etc.	6
Power System Automation Equipment	synchronous generator automatic excitation regulation, power system frequency and active power automatically adjust, power system security control device, etc.	7
Renewable Power Generation Technologies	status of international energy issues, principles of new energy power generation, Maximum Power Point Tracker (particular), grid-connected equipment and technologies (particular), etc.	7

2) *Power transmission:* The main duty in this domain involves power dispatching, line inspection and line reparation. So, another four courses, "Power System Relay Protection", "High Voltage Technology", "Power Line Operation and Maintenance", "Integrated Substation Automation", are offered. The main contents and the opening semester are showed in Table II.

TABLE II: FOUR COURSES IN POWER TRANSMISSION

Course	Main content	Term
Power System Relay Protection	overcurrent protection, distance protection, longitudinal differential protection, microprocessor-based protection, etc.	6
High Voltage Technology	atmospheric overvoltage, lightning protection , electrical insulation and insulation resistance testing method, high voltage test, etc.	6
Power Line Operation and Maintenance	power line components and electrical characteristics, operation specifications, maintenance, etc.	7
Integrated Substation Automation	protection and Monitoring of main transformer, spacer cable, automatic control devices, data communications, reliability issues, diagnosis and treatment of common faults, etc.	7

3) *Power supporting:* The courses of this module are for students willing to work in power supporting industries such

as automation operation, equipment manufacturing and power construction. So, another four courses, “Sensor and Detecting Technology”, “Computer Control Technology”, “Electrical Control and Programmable Logic Controller”, “Power Engineering Project Management”, are offered. The main contents and the opening semester are showed in Table III.

TABLE III: FOUR COURSES IN POWER SUPPORTING

Course	Main content	Term
Sensor and Detecting Technology	error analysis, detection methods, temperature sensor, photoelectric sensor, speed sensor, etc.	6
Computer Control Technology	computer control system and interface, industrial network and communication technology, industrial controller, etc.	6
Electrical Control and Programmable Logic Controller	motor’s start-up, speed regulation and brake, computerized numerical control machine (CNC), programmable logic controller(PLC)	7
Power Engineering Project Management	legal person responsibility system, biding system, project supervision system, contract system, project management software, etc.	7

B. Project Design Courses

The design of project design courses is to enhance the engineering practice capacity required for career. In the Fig. 3, four-level PD courses are weaved in basis courses and professional courses. The main line of “cognitive training - basic engineering and professional courses & labs - project design – professional module courses & labs - integrated design – graduation project”, is formed, and it meets the cognitive law of practice – theory – practice.

Level-1 PD, “Basic Electronic Technology Training”, is offered in 3rd semester. The complete project is taught with the decomposition of functional modules, so as to help students establish perceptual awareness of component - circuit - system. The study of practical projects can stimulate students’ interest in their major and study. Meanwhile, basic welding technology and skills are required to master, which are used in the following project design course.

Level-2 PD, “Project Design I”, is offered in 5th semester. It is based on SCM, while design topics and requirements are given by teachers. Teachers help students establish the initial awareness of C-D-I-O process. The design requires teamwork and is assessed in the form of project report and presentation.

Level-3 PD, “Project Design II”, is offered in 7th semester. With base theories from professional module courses, students design the topics by themselves. For example, substation design for who learn courses about power generation, design of power supply and distribution system in the small and medium factories for who learn courses about power transmission, design of express sorting system based on PLC for who learn courses about power supporting. Electing courses in two modules, students can undertake integrated design projects, such as design of double-fed wind generation control system based on PLC. The project design followed C-D-I-O process will further improve students’ engineering capacity. The design requires teamwork and is assessed in the form of essay and defense.

Level-4 PD, “Graduation Project”, is offered in 8th semester. Engineering topic means thesis topic derives from the actual project of internship or job, or from school-enterprise cooperation project. The graduation theses need to be completed independently, but they could be the different designs from the same topic. The same topic is good for students to discuss, while the different design is beneficial to cultivate innovative thinking.

C. Career Guidance Courses

The design of career guidance courses is to build the career planning awareness and improve job search skills. In 1st semester, the evaluation of students’ character and ability, and the cognition of CDIO Syllabus are carried out, which help students recognize themselves objectively and clear career orientation. Choose the professional module courses according to their interests and strengths, and strengthen certain abilities according to their weaknesses and needs. In 7th semester, resume writing, mock interview and work experience sharing are carried out, which increase students’ success rate in job hunting.

IV. CDIO-ORIENTED INNER LOOP

A. CDIO Syllabus

CDIO Syllabus defines engineering knowledge, personal skills, interpersonal skills and C-D-I-O skills what engineers need. Student outcomes corresponding to these four aspects meet the requirements on applied and compound talents. The traditional curriculum has been able to ensure the building of engineering knowledge. The professional module courses and project design courses in part III improve C-D-I-O skills. But the supporting of personal skills and interpersonal skills is weak. Therefore, in order to achieve full coverage of student outcomes, some points need to be purposefully incorporated into the curriculum.

In CDIO Syllabus, “2.2.2 Survey of Print and Electronic Literature”, “2.4.4 Critical Thinking”, “3.1 Teamwork” and “3.2 Communications” can be cultivated in “Project Design I”, “Project Design II” and “Graduation Project”. For example, students need to do literature search or patent search to find the similar topic or project design. Other three points are proved by project discussion, problem analysis and improvement among team members, or between students and teachers.

In CDIO Syllabus, “2.5.4 Staying Current on the World of Engineering” can be cultivated in “Renewable Power Generation Technologies”. For example, the largest single solar farm in Ningxia Province of China, the second largest installed capacity of solar farm in California of America, the largest wind farm in Jiuquan of China, the largest tidal generating station in Puntland Strait of England, these cases and related key technologies are introduced in this course.

In CDIO Syllabus, “4.1.6 Developing a Global Perspective” can be cultivated in “Discipline Lecture” and some professional courses. In recent years, global mindset and internationalization in engineering education have received more and more attention. Emerging a number of reform programs. Much of them are about exchange students, joint education, summer internship, which all called Going Out Mode. But for some regional universities, poor language and academic ability of students, high cost of study abroad increase the difficulty of Going-out Mode. However, Bring-in Mode is feasible. Invited to give lectures, foreign teachers or business representatives introduce EE's situation in their universities, the work content in power industry, the implementation mode in power project, also popularize their culture, policies, laws, regulations. Moreover, energy and environmental pollution are global issues that are closely related to EE. The cases of energy saving or pollution controlling should be injected into some professional courses.

B. ITU Skills

During the implementation of curriculum, the rational use of ITU skills benefits the achievement of student outcomes. Due to the difficulty of knowledge, the difference of course objectives and the relationship between knowledge and engineering practice, different courses should be imparted with different teaching skills. The same goes for the different stages or contents in the same course.

Introduce skill applies to the content of remember-level or the preliminary stage of the indigestible knowledge. For example, the contents of "Introduction to Electrical Engineering" are too many, very complex, and closely linked with the following professional courses. Without any foundation of professional knowledge, this course should be imparted with Introduce skill. Teachers focus on basic concepts, basic principles and basic structure of knowledge, while the details of work are left to be analyzed in the following professional courses.

Teach skill applies to the content of understand-level, application-level and analysis-level. For example, different combinational circuits in "Power Electronics" have different functions and strong applicability. This course should be imparted with Teach skill. Teachers focus on the relevant circuit characteristics, analytical methods and the roles of components. Noteworthy, for students of regional universities, knowledge points should be taught with the purpose of practicability and the degree of adequacy. For example, about the three-phase short circuit fault of the unlimited capacity system in "Power System Analysis", there are a large number of formula derivations and model conversions in its textbook. In order to save class hours and reduce students' burden, teachers emphasize the analytical approach and the conclusion. It is enough for students to understand and remember the characteristics of current and impedance in the short circuit, and know how to use in the protection relay of follow-up course.

Utilize skill is to assess students' proficiency in knowledge and technical skill. For example, staffs who do electrical design, electrical construction or equipment production need to recognize, draw or design schematic. So "Electrical Practical CAD" should be imparted with Utilize skill. In the early stage of this course, explain how to use the software, its various tools, and the design specification. In the mid-term, teachers dissect the existing schematic into modules by function. Let students copy it from part to whole. In the latter stage, teachers demonstrate and explain the functions of electrical product. Students design its schematics, which is called reverse CAD approach.

V. CONCLUSION

The paper designs an EE curriculum which has the following features: 1) Breaking the tradition curriculum based on the knowledge structure of discipline, new curriculum is a double closed-loop model with a career-oriented outer loop and an CDIO-oriented inner loop. 2)The curriculum is a two-dimensional one. The horizontal axis is three modules according to the career classification, and the vertical axes respectively follow the progressive relationship of the theoretical knowledge and engineering practice. The courses at different levels are progressive and mutually supportive. The practice objectives at different levels are increased step by step.

Indeed, any curriculum revamp effort is to some extent an experiment. Challenges has been foreseen: 1) New courses are thought as addition to faculties' already-heavy workload. 2) Faculties are lack of understanding of CDIO Syllabus. They are seasoned speaker of knowledge, but they are novices to incorporate CDIO Syllabus into the curriculum. 3) Assessment is a hard work.

However, special measures are needed: 1) The university as sample has set up a Regulatory Commission composed of industry professionals, academic experts, institute leaders and teacher representatives. New EE curriculum has been passed by the commission. 2) Teacher-student evaluations and conversaziones are listed as a necessary part of assessment. 3) Teacher's engineering training is under way. 4) Complete laboratories and cooperative enterprises are requirements for engineering practice.

Although this paper takes a university in Yunnan as example, the methodology of using CDIO to design a career-oriented curriculum also applies to other regions with different career characteristics. And it works in other disciplines or majors.

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