RESEARCH AND PRACTICE ON CULTIVATING ENGINEERING ABILITY- ORIENTED STUDENTS WITH A MAJOR IN AUTOMATION

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ABSTRACT

Based on the school orientation, and CDIO engineering education model, the paper elaborates on the research and practice of the model to cultivate engineering ability-oriented and high-quality applicable students with a major in automation, by setting clearly defined cultivation objectives, exploring quality-oriented education, establishing the knowledge and ability system, developing training programs, integrating curriculum, launching practice and teaching platforms on and off campus, implementing educational reform, evaluating cultivation objectives and continuously adjusting the thoughts of the training aspects. This model has been implemented and achieved significant results in the Pilot Plan of Cultivating Excellent Engineers authorized by the Ministry of Education in Automation Department of our school.

KEYWORDS

CDIO, Cultivating Mode, Ability and Quality, Automation.

1 INTRODUCTION

With the popularization of higher education, colleges and universities play a pivotal role in the economic and social development. As a local university, we are facing such great opportunities and challenges in our engineering majors as building appropriate educational environment suitable for students, implementing engineering education reform, training high-caliber, practice-oriented talents meeting the needs of the society. CDIO engineering education model aims to foster the students' engineering ability, through the entire lifecycle of modern industrial products from their conception, design to operation and disposal [1] [2]. On the basis of this model, we help students develop engineering expertise, individual qualities and teamwork spirit by setting clearly defined cultivation objectives, exploring quality-oriented education, establishing the knowledge and ability system, developing training programs, integrating curriculum, launching practice and teaching platforms on and off campus, implementing educational reform, evaluating cultivation objectives and continuously adjusting the thoughts of the training aspects.

2 EXPLORE THE CULTIVATION MODEL OF CDIO-BASED APPLICABLE ENGINEERS

To determine training objectives is the first step towards the exploration of talents cultivation model which varies in the targets. They can be divided into type, profession and competence goals. The first one defines the type attributes, features and specifications of personnel training; the second one specifies the professional attributes, features and orientation; the third one is specific requirements to achieve both the first and second ones. These three together constitute a complete training model.

CDIO engineering education model sets in the context of conception, design, implementation and operation processes. In the view of competence, “conception” is to establish the engineering way of thinking, "design" to obtain all-round capabilities translating ideas into detailed plans; "implementation" to master the technology transforming the design into reality, "operation" to have good communication and co-ordination skills. That particular emphasis is laid on one certain ability will lead to different type objectives and engineering education models. To be specific, if more weight is placed on "conception" and "design", this model will emphasize to develop students into R&D-oriented engineers with engineering and technical research and development abilities while cultivate their engineering thinking, organization and coordination abilities; if on "design" and “implementation”, design-oriented engineers with comprehensive design abilities; if on "implementation" and "operation", practice-oriented engineers with technical application abilities. Also, there are specialized research and development, engineering and industrial engineers in today’s large enterprises. Our school is positioned as a distinctive high-level, application-oriented university, and the type objective of our automation major is to prepare students for applicable engineers [3].

In determining the profession objective, considerations should be given to students' growth and social demands. From students’ point of view, they will lay a solid foundation in engineering quality, capability and application either for employment or for further study; from the society, it requires "products" and "systems" for automation majors who are able to design, manufacture, market and maintain products with automatic control systems, to provide the basic program, system integration, construction, and technical support for engineering projects with automatic control systems. When it comes to automation major, most of the colleges and universities still have a long way to go in terms of education philosophy, cultivation models, curriculum system, teaching content, teaching methods. Especially in engineering design, system integration, site construction, system operation, installation and maintenance of automatic control systems, a gap is greater in the teaching content, curriculum provision, professional faculty, and practice platform. Our profession objective is to prepare students for automatic system engineers.

Ability and quality goals are designed to cultivate general engineering abilities and professional competence. In light of the syllabus of CDIO, the criteria of ABET accreditation and requirements of enterprises for qualified personnel, we have identified ten targets of general engineering abilities, that is, engineering reasoning (recognition, modeling, solution), comprehensive use of technology, skills and modern engineering tools to tackle problems, conducting experiments to search for knowledge, systematic, creative and critical thinking, the correct understanding of professional ethics, social ethics and responsibilities, the sense of lifelong learning, learning ability, team organization, coordination and integration, effective interpersonal communication and presentation skills, a broad vision on engineering related to global, economic, environmental and social impacts and related contemporary issues [4] [5]. Through surveys of graduates, academic analysis, industry analysis, growth analysis of typical professionals, we have identified seven ability and quality objectives for students major in automation, namely, the application of mathematics, natural sciences and engineering, the integrated design of electronic systems, the programming of industrial control systems, the analysis and design of automatic control systems and digital simulation, automatic control system design and product integration, automatic control system installation, commissioning, operation and maintenance, and participation in enterprise practice.

The above comprehensive analyses show that our school is a local normal university with ample experience in the automation field, and that the cultivation objectives aim to bring forth application-oriented automation engineers with ten general engineering and seven automation abilities and qualities.

To achieve these objectives, we have set up the cultivation model for CDIO-based, application-oriented automation system engineers, as shown in Figure 1. Cultivation objectives are consistent with social demands and student development needs. We realize these objectives by linking up knowledge and ability systems, training programs, curriculum system and teaching process with abilities and qualities as a main thread. Results are fed back to teaching processes by students, teachers and the society. The training puts emphasis on engineering ability, quality and implementation, forming the cultivation system for engineering application-oriented talents through giving priority to abilities and qualities, providing dynamic feedback, and meeting the needs of students and the society.

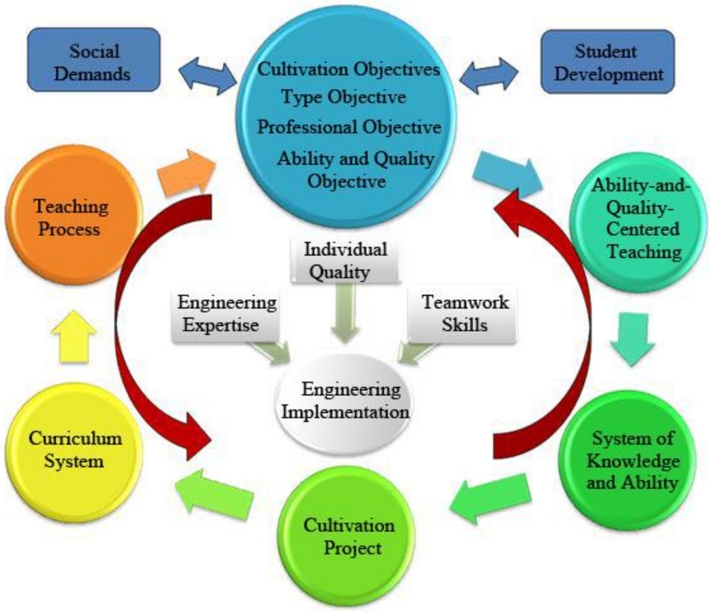

Figure 1. Cultivation Model for CDIO-based, Application-oriented Automation System Engineers

3 CULTIVATION PROJECT BASED ON ENGINEERING ABILITY AND QUALITY FOR AUTOMATION MAJORS

3.1 Knowledge and Ability System Based on Engineering Ability and Quality

The professional education revolves seven ability and quality objectives for students major in automation, as shown in Figure 2 fish bone diagram. Each goal requires one or two knowledge modules, each of which comprises several courses or teaching processes. One basic knowledge and ability module for the core engineering is adopted to cultivate abilities in electronic system integrated design and programming of industrial control systems; this module, together with another advance module of engineering technology, expertise and competence to cultivate the analysis and design of automatic control systems and digital simulation; two of the advanced modules to cultivate the design, installation, operation and maintenance of automatic control systems and product integration; two processes of enterprise practice to cultivate practical working abilities. Following this step-up training system and gradual improvement modules, we have built the complete knowledge and ability system with ability module, basic knowledge and ability module for the core engineering, and advanced module for engineering technology, expertise and competence.

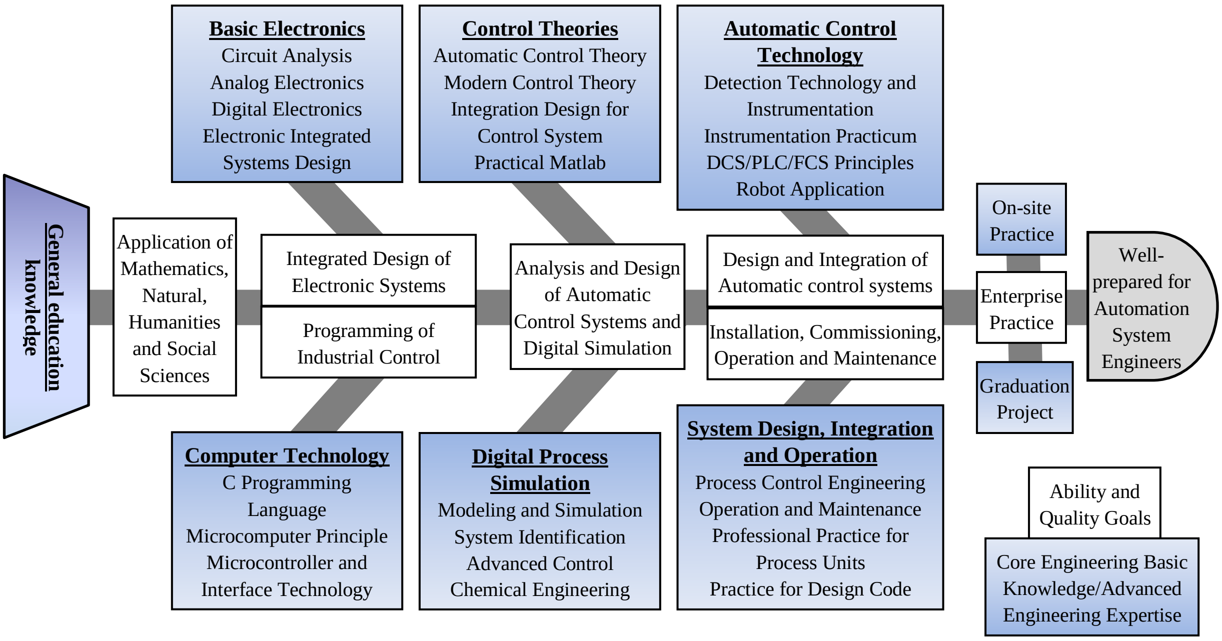

Figure 2. Knowledge and Ability System Based on Engineering Ability and Quality for Automation Majors

3.2 Integrated Curricula

According to the fish bone diagram of ability and quality, we integrate our courses, and develop the curriculum system following the main line of engineering ability and quality, as shown in Figure 3.

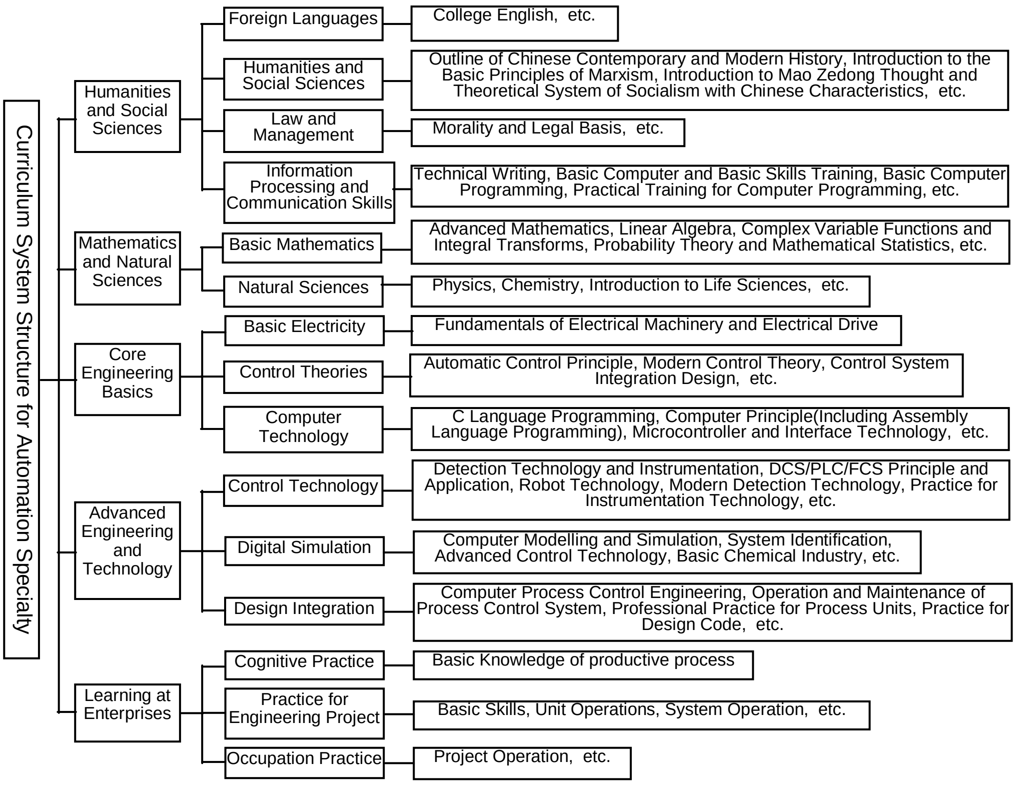

Figure 3. Curriculum System based on engineering ability and quality for Automation Majors

The integrated curricula emphasize the engineering ability, quality and teaching practice. The new form of courses include Instruction with Lectures; Instruction with Enterprise Visits; Laboratory Teaching; Course A (on-campus theoretical teaching) with Course B (on-site practicum); inviting enterprise engineers to lecture in our university. Centering around the actual devices or projects, the original courses are integrated into the series lessons of engineering education courses taught by school faculty and enterprise professionals, so as to help students have a complete understanding of the entire engineering lifecycle (CDIO mode) from system design, product integration, engineering installation, system commissioning to device installation, operation and maintenance.

With one year of practical experience in enterprises, a teaching system is constructed in the new courses, as shown in Table 1.

Table 1 Curriculum System with One Year of Practical Experience in Enterprises

Course Title	Credits	Hours	Semester	Description
Automation Introduction	2	16*2	The 1st,5th Semesters	Visit Yanshan Petrochemical (one day); automated production line of Beijing Hyundai Motor (one day); sales department of automatic control products in Zhongguancun (one day). Have a preliminary understanding of automation products and control systems and inspire students' interest.
DCS / PLC / FCS Theories and Application B	2	16 Hours +2Weeks	The 7th Semester	The follow-up curriculum of Course A provides extensive knowledge of products from different manufacturers, and of laboratory, operation and maintenance practices.
Professional Practice for Process Units	1	1 week	The 7th Semester	Assign the task of automatic control design according to the hydroisomerization unit process.
Professional Practice for Instrumentation Technology	1	1 week	The 7th Semester	Complete the removal, maintenance, calibration, installation and integrated test of various types of instruments on the hydroisomerization unit.
Computer Process Control Engineering B	2	16 Hours +2Weeks	The 7th Semester	In the production of devices for "Computer Process Control Engineering " on-site teaching and practice to complete the oil-chemical process system design, implementation, commissioning and other tasks.
Advanced Control Technology	2	2 Weeks	The 7th Semester	In the simulation system to carry out self-tuning, predictive control, optimal control, the actual operation of advanced control software package.
Process Control, System Operation and Maintenance	2	2 Weeks	The 7th Semester	Operation and maintenance of hydroisomerization process control system devices.
Practice for Design Code	1	1 Week	The 7th Semester	To institute or post-graduate units, control engineering internship to learn more about the project design and implementation process.
On-site Practice	8	14 Weeks	The 8th Semester	Attach importance to safety, explosion-proof, self-protection study of oil and chemical plants; learn the application of automatic technology in factories, master the basic skills

				required for field engineers of automatic control instrumentation during the petrochemical process; understand the responsibilities and work scope of automation engineers, etc.
Graduation Project	8	16 Weeks (non-intensive)	The 8^{th},9th Semester	Prepare graduation project and thesis proposal separately; arrange project throughout the school year under the guidance of tutors.

Table 2 shows the integrated curricula of basic computer modules. Generally, most of the students lack the practical experience in basic operation and have little understanding of engineering culture before learning the engineering courses, which fundamentally hinder their from the growth in this field. In the module, the course of "Practice Training of Computer Programming Skills" is designed to help students have an early experience of project-based engineering in their first school year, and set up a basic framework of engineering science, the expertise and engineering capability. Specifically, small robots are used as the engineering object, which will be controlled by students on the C language programming platform for robots. This practice will enhance their interests in learning, reveal engineering-oriented concept, develop their skills in C language programming to solve practical problems and obtain the preliminary experience of engineering to smoothly start the follow-up courses.

Table 2 Integrated Curricula of Basic Computer Modules

Original Course	Integrated Courses	Capacity Building
Basic Computer Skills Training; College Basic Computer; Basis for Computer Programming; Course Design	Basic Computer and Skills Training; Basis for Computer Programming Practical Training for Computer Programming	Computer Programming Skills

Table 3 shows integrated curricula of basic electric module. Part of the experiments, application of EDA technology, curriculum design, electronic practice for electricians are integrated into the comprehensive course of electrical engineering design which will be finished in two semesters. Every student is required to design and produce a practical electric system with complete functions under the guidance of teachers during the basic electric courses. Specifically, the electronic system is divided into several modules on the basis of teaching progress and content. Students are expected to design the corresponding module in each semester, complete the whole system design and production after the courses of basic electronic system. The target aims to furnish students with electronic system design capability. Outstanding students are able to acquire Electronic Design Engineer Certification issued by Chinese Institute of Electronics.

Table 3 Integrated Curricula of Basic Electric Module

Original Course	Integrated Courses	Capacity Building
Circuit Analysis; Analog Electronic Technology; Digital Electronic Technology; Electronic Technology Experiment; Electronic System Simulation; EDA Technology Application; Modern Electronic Design; Electronic Practice for Electrician;	Circuit Analysis; Analog Electronic Technology; Digital Electronic Technology; Electronic Engineering Design (I); Electronic Engineering Design (II)	Integrated design capability of electronic systems

Electronic Course Design		

Table 4 shows the integrated curricula of computer technology module. One practical application system should be developed to further improve the practice ability in engineering.

Table 4 Integrated Curricula of Computer Technology Module

Original Course	Integrated Courses	Capacity Building
Microcomputer Principle; Interface Technology; Comprehensive Experiment of Interface Technology	Microcomputer Principle and Interface Technology; Practical Training of Microcontroller Engineering	Hardware system development

Table 5 shows the integrated curricula of control theory module. Theory course is introduced to the classroom. One robot with the feedback function is shared by two students to learn the control theory while make it into practice. The integrated design for control systems highlights comprehensive and systematic abilities, from which students can implement the design and control of small controllable devices.

Table 5 Integrated Curricula of Control Theory Module

Original Course	Integrated Courses	Capacity Building
Automatic Control Principle; Modern Control Theory; Course Design for Automatic Control	Automatic Control Principle; Modern Control Theory; Integrated Design for Control Systems	Analysis and design abilities of control systems

Table 6 shows the integrated curricula of process digital simulation module. Matlab practical course is learned by students themselves and ahead of the original arrangement. In the advanced control technology course, on-campus theory teaching is adopted, combined with the operation of imported control software at the Education and Training Center of Yanshan Petrochemical. Our school and the company mutually develop the advanced control software and process simulation system.

Table 6 Integrated Curricula of Process Digital Simulation Module

Original Course	Integrated Courses	Capacity Building
Computer Modeling and Simulation; Matlab Practice; System Identification; Advanced Control	Computer Modeling and Simulation; Advanced Control Technology; System Identification	Digital simulation ability of control systems

Table 7 shows the integrated curricula of automatic control system design, integration, operation and maintenance modules, which are taught both by school faculty and enterprise professionals to achieve a complete teaching process of engineering practice.

Table 7 Integrated Curricula of Automatic Control System Design, Integration, Operation and Maintenance Modules

Original Course	Integrated Courses	Capacity Building
Detection Technology and Instrumentation; Subject Experiments for Detection Technology; Distributed System; Programmable Controller; Field Bus Technology and Application	Detection Technology and Instrumentation Instrumentation Technology Professional Practice DCS / PLC / FCS Principle and Application of A DCS / PLC / FCS Principle and Application B	Process control system design, installation, commissioning, integration, operation and maintenance
Process Control Engineering; Computer Control System; Professional Practice; Integrated Course Design; Subject Experiments for Control Systems Graduation Project (Thesis)	A computer process control engineering Computer Process Control Engineering B Process units Professional Practice Process control system operation and maintenance Design practice Attendant training Graduation Project (Thesis)	

3.3 Construction of On-and-Off Campus practice and teaching Platform

A high-level on-and-off campus practice and teaching base should be established in order to achieve the course system centered on the cultivation of engineering ability and quality for automation majors

3.3.1 Construction of Off-Campus Practice and Teaching Base

To integrate industry culture into university, our school has carried out in school-enterprise cooperation with Yanshan Petrochemical Company, introduced the workplace into the classroom throughout the entire education process. According to the philosophy of "fine education", we endeavor to create the well-designed school-enterprise model, by carefully carrying out the cooperation model and content, company training programs, detailed company training programs and lectures delivered by enterprise experts to our school; implementing each cooperation task; managing the quality of every aspect and providing the reliable supports for students. We will develop the cooperation in a more extensive and profound way, to doing fine, been done, for students to create the first-class, non-virtual situations which make it possible for students to enjoy quality engineering education and practice.

(1) Curriculum System Jointly Developed by the School and Enterprise. According to the actual position requirements of automated systems engineers, we build a scientific curriculum system of engineering education for automation specialty to emphasize engineering ability and quality, and develop training programs to provide the education satisfying the needs of society, by combining the features of academic courses with the advantages of enterprise training programs, after the discussion with engineering and technical experts from Yanshan Petrochemical. Both sides establish a regular meeting system to have an in-depth discussion on a regular basis in respect of the implementation of this curriculum system.

(2) Teaching Staff mutually selected by the school and enterprise. Through the school-and enterprise cooperation, we have complementary advantages of university teachers and corporate engineers. On the one hand, lessons can be taught by them either separately or jointly; on the other hand, they are able to share experience and practice opportunities during the teacher training. In this way, our teachers will greatly improve the experience and

capability in engineering practice and improve the capacity and level of engineering practice. A new “Teacher-Engineer” model is jointly set by experienced teachers and outstanding engineers.

(3) Courses Mutually formulated by the school and enterprise. Following the enterprise workflow, requirements of job skills and the overall quality, we determine the course structure, select course content, and develop professional teaching materials in order to introduce the most required knowledge, the most critical skill, and the most important quality to our students, in close connection with actual operation and recruitment requirements. Taking the series practice courses at the enterprise will be replaced displace the simple on-site training. The series “Excellent Engineer Plan for Automation Specialty” is co-written by two sides.

(4) Classroom Mutually Organized by the School and Enterprise. The enterprise provides the practice base outside the campus, and assigns technical experts and managerial talents to act as teachers so that students will improve their abilities in the real engineering environment. At the same time, we invite experienced engineering and technical personnel to deliver lectures in our school. The classroom teaching is carried out through the joint efforts of the school, enterprise and society.

(5) Extracurricular Technical Activities jointly held by the School an Enterprise. The performance of extracurricular activities is dependent on the quality of instructors. Enterprise technical experts and our teachers give tutor the students throughout the entire process of such activities which are held once of every one to two weeks. Two sides will organize students to report their research progress, exchange the results, and share their experience, and answer their questions, according to scientific research training and project management requirements. Besides, students are greatly encouraged to make active use of the school’s education resources, to bring their initiative into full play, to promote teamwork and joint innovation. This measure is a best practice of “project teaching method”.

With the joint investment of our school and Yanshan Petrochemical, we created one hydroisomerization unit at the company, shown in Figure 4. Installed with a large number of detection and control instruments, as well as DCS control system, it is used to help students install instruments, learn DCS configuration, system debugging, unit operation, production, and maintenance, nearly covering all main contents of process control systems. Automation majors can apply their knowledge into practice, such as, project construction, operation, maintenance and basic program design. Based on this device, several courses on process control are integrated to the series of engineering education, with the measure of Project Bootstrap. Both sides co-authored supporting textbook Practice of Controlling Process Production Units (graded as Beijing excellent teaching material) is to be published.

Figure 4. Hydroisomerization Unit at Yanshan Petrochemical

3.3.2 On-Campus Practice and Teaching Base

The school laboratory simulates the actual work environment. The entire platform is similar to a plant, with each laboratory as its work shop. As the production devices, experiment units are consisted of small control systems which are controlled by the network. The simulated automation factory has such business organization as field control, workshop scheduling, and plant management, to create a virtual industrial process and achieve the real control. Students will benefit from the real work place. Now, the experiment devices include Ethylacetate production training equipment, pure water production training equipment, flow control equipment of liquid level pressure, water control system, process simulation and control equipment, various types of inverted pendulum systems, all kinds of ball and beam systems, elevator control system, rotor flight control system, flight control system of flapping wing, etc. Control systems contain the U. S. States Honywell PKS, SUPCON ECS-700, JX-300 and Siemens PCS7 distributed control systems, etc. In addition, the laboratory possesses Siemens S7-300/400 PLC, frequency control devices, PROFIBUS, DeviceNet, FF, industrial Ethernet, and German Wago field bus devices. The control room of experimental platform is shown in Figure 5.

Figure 5. On-Campus Control Room of Experimental Platform

3.4 Implementation of Curriculum Reform

Curriculum reform is the key to implementing the cultivation model for high-level, practice-oriented automation majors centered on engineering ability and quality. Starting from the formulation and implementation of syllabus, we focus on course description, course teaching targets (students to achieve), mapping relations between curricula and professional training objectives. Table 8 shows course description, teaching objectives and syllabus template (part). Output model is adopted in the mapping relations between curricula and professional training objectives. The goal to cultivate professional ability and quality refers to the output index system to evaluate students' learning outcomes after the courses. We set up the mapping relations (Table 9) on the basis of in-depth study of the teaching process, and teaching methods. The clear analysis and gradual implementation of this mapping is the process to deepen teaching reform. One process of each course corresponding to one certain teaching method will reach the related output index which will be identified by students, teachers and expert panel from different views and adjusted during the teaching process. Every course will educate the part of engineering ability and quality. The set of courses will gradually develop the professional ability and quality of students and prepare them for automation system engineers.

Table 8 Syllabus Template (Part)

Course Description	is a compulsory professional course for specialty. This syllabus is prepared in accordance with the cultivation objectives of specialty. It is an application-oriented and highly practical course, which elaborates on the principle of . The teacher will instruct students to build on the basis of . Students will master with the use of and the application of . The content mainly covers . The study will help students acquire the ability of , to lay the foundation for their future work in the field of .
Course Teaching Objectives (Students to Achieve)	After the completion of this course, students should be able to attain the following requirements: <u>Knowledge</u>: install / explain / use / create ; <u>Ability</u>: have the ability of ; <u>Awareness</u>: foster the awareness of ; <u>Quality</u> develop the quality of .

Table 9 Mapping Table for Courses and Professional Cultivation Objectives

Mapping Table for 《 》Course and Professional Cultivation Objectives

Teaching Processes	Teaching Methods	General Cultivation Objectives for Engineering Education										Cultivation Objectives of Ability and Quality for Automation Specialty						
		Engineering Reasoning (Recognition, modeling, solving)	Comprehensive Use of Technology, Skills and Modern Engineering Tools to Solve the Problems	Conduct Experiments and Explore the knowledge	Systematic Thinking	Creative and Critical Thinking	Correct Understanding of Professional Ethics, Social Ethics and Responsibility	Correct Understanding of Lifelong Learning and Study Ability	Team Organization, Coordination and Integration	Effective Interpersonal, Communication and Presentation Skills	Influence of Engineering on the World, Economy, Environment and Society and the Awareness of Contemporary Issues	Application of Mathematics, Natural Sciences and Engineering	Integration Design of Electronic Systems	Industrial Control Computer Programming	Analysis and Design of Automatic Control Systems and Digital Simulation	Automatic Control System Design and Product Integration	Installation, Operation and Maintenance of Automatic Control Systems	Enterprise Practice Capacity
Theory Teaching	**Classroom Teaching**																	
	Laboratory Teaching																	
	Focus Discussion																	
	Project Learning																	
	Enterprise Lectures																	
	Self-Study																	
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Practice Teaching	**Personal Practice operation**																	
	Group operation																	
	Enterprise Implementation																	
	Project Practice																	
	Independent Practice																	
	……																	

Assessment	Written Examination																	
	Operation																	
	Oral Defense																	
	Thesis																	
	Open Assessment																	
	……																	

4 CONCLUSION

From the positioning of our school, this paper elaborates on the systematic engineering thinking for cultivation objectives, which is explored and applied in the cultivation model for high-level practice-oriented automation majors based on engineering ability and quality, according to training objectives, ability and quality, knowledge and ability systems, training programs, courses, practice teaching platform, and curriculum reform. This model has been implemented by the Department of Automation in our pilot project of Outstanding Engineer Cultivation supported by the Ministry of Education with remarkable results. We have completed the syllabus, and smoothly cooperated with the enterprise to carry out the teaching process, largely improving the ability of quality of students, and creating better study atmosphere.

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