Construction of a Curriculum System for the Integration of Industry and Education in the Robotics Engineering Major of Applied Universities

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Received Nov. 19, 2025; Revised and Accepted Nov. 24, 2025

Abstract. This study designs a curriculum system that deeply integrates industry and education for robotics engineering majors in applied universities. Guided by the CDIO philosophy and the concept of industryCeducation collaboration, a three-level curriculum framework consisting of foundational courses, professional cores, and integrated practical modules is constructed. Industry technologies and standards are introduced into course content, teaching methods, and evaluation systems through co-developed courses, shared laboratories, and joint faculty teams. The system emphasizes continuous engagement with real-world engineering projects, fostering students' competencies in design, programming, integration, and innovation. The proposed model provides a flexible and sustainable approach for cultivating application-oriented robotics talents that meet the evolving needs of intelligent manufacturing.

Keywords: Industry-education integration; Robotics engineering; Applied universities; CDIO curriculum.

1. Introduction

Intelligent manufacturing, as the development direction of the manufacturing industry, is driving the transformation and upgrading of the manufacturing sector. Robot technology plays a crucial role in intelligent manufacturing and has become an important driving force for the technological revolution and industrial transformation [1-5]. To vigorously cultivate high-end talents in robot technology, robot engineering, as the first batch of "new engineering disciplines", was first introduced by Southeast University in 2016 and has been offered by 367 universities across the country by 2024. Different from traditional engineering disciplines, robot engineering involves the interdisciplinary integration of mechanics, electrical engineering, electronics, computer science, and control, and has very high requirements for the breadth and depth of knowledge in talent cultivation. Due to the late start of the construction of the robot engineering major, each university is still in the stage of building the curriculum system. Compared with research-oriented universities, application-oriented universities, as an important force for cultivating applied talents, pay more attention to cultivating applied engineers and emphasize the ability to solve practical engineering problems. In recent years, many universities have actively explored distinctive robot engineering curriculum systems, such as Qingdao University of Science and Technology exploring a multi-disciplinary integrated theoretical curriculum system and a project-driven practical curriculum system, Xi'an University of Technology exploring a curriculum system based on "theoretical teaching + practical teaching" two main lines, Beijing University of Science and Technology creating a "immersive" innovative practice curriculum system that integrates the entire academic program, Guangdong Maritime University constructing a practical curriculum system integrating the OBE concept, Shaoguan University constructing a category + module curriculum system. Nanchang Institute of Technology set up the industrial robot direction in the mechanical and electronic engineering major in 2018 and began to recruit students for the robot engineering major in 2021. This article will introduce the exploration ideas of the curriculum system of the robot engineering major at Zhengzhou University of Science and Technology, focusing on the theoretical and practical curriculum system design based on the training objectives, as well as the implementation measures and effects of the curriculum teaching [6-8].

From the current development situation of industry applications, robots include industrial robots, service robots, collaborative robots, and special robots, etc. Among them, industrial robots are an important carrier of digital intelligent manufacturing, because the research and industrialization application of industrial robots is one of the important indicators for measuring a country's scientific and technological innovation and high-end manufacturing development level [9-13]. However, with the adjustment of the industrial structure and the transformation and upgrading of the manufacturing model, the contradiction between the supply and demand of talents in China has become increasingly prominent, and more and more enterprises are facing the problem of "easy access to equipment but difficult to find talents". Xu et al. [14] studied that it is necessary to vigorously cultivate skilled and technical shortage talents, encourage universities and enterprises to cooperate, build a batch of shortage talent

training and training bases for key manufacturing fields, and carry out order-based training. Therefore, universities need to quickly plan, steadily promote and develop educational work in the field of intelligent manufacturing, cultivate and reserve high-quality applied talents with innovative and practical abilities in the field of intelligent manufacturing, and provide important guarantees for exploring robot technology and industrial innovation fields.

As our country gradually enters an aging society, the number of young labor force in all social strata is decreasing. However, the current industrial development model in our country is still dominated by the manufacturing industry of the secondary sector. This industrial development model requires a large number of young and healthy labor force. From the current situation, our country has become a major country in industrial robot manufacturing [15-18]. Due to the decrease in the number of young and healthy labor force in our country, the demand for industrial robots has been increasing, gradually making our country a major country in industrial robot manufacturing in the world. The increase in the demand for industrial robots to some extent can effectively promote the upgrading of our country's industry. With the increase in the demand for industrial robots in our country, the demand for professional talents in industrial robot operation and maintenance has also gradually increased. However, in the actual process of the development of industrial robots in our country, the actual phenomenon is that there is a shortage of professional talents. Because industrial robots have high requirements for the quality of employees, and the supply of talents in our country cannot keep up with the speed of this industrial robot development, this is also a major problem that our country needs to solve at present.

2.   Problems Existing in the Talent Cultivation Model

At present, in order to address the issue of insufficient demand for professional high-quality talents, our country has proposed that various vocational schools should develop professional courses integrating industrial robots into education. However, due to the limitations of our country's technological level, there is a lack of professional theories in the field of industrial robots. The imperfection of the theories makes it impossible for students in vocational schools to achieve excellence when learning the theories related to industrial robots. This outdated theory mode is seriously hindering the process of making our country's industrial robot development level on par with the international level. Moreover, in the process of cultivating high-tech talents of this profession, the technical talents produced by vocational schools receive much less social recognition compared to those from universities. This has seriously dampened students' enthusiasm for studying this profession and reduced the number of professional talents in this field. The research investment in industrial robots in our country is also insufficient, which has seriously hindered the independent research and development process of industrial robots in our country [19-22].

In the talent cultivation model, the existing problems mainly lie in the following three aspects: Firstly, the course system structure in the original talent cultivation plan is not complete enough, lacking innovation and entrepreneurship education as well as second-class classroom practice, which fails to well reflect the goal of cultivating applied talents; Secondly, regarding how courses support graduation requirements, this aspect was not reflected in the original talent cultivation plan, resulting in teachers merely imparting the relevant knowledge points of the courses in the teaching process without connecting them with the major, and after students complete the courses, they are not clear about the significance of learning this course, and there is a lack of correlation between the course and the major; Thirdly, the training of students' practical abilities is not systematic enough. During their school years, students' acquired theoretical knowledge has a certain gap compared to the ability required to solve practical engineering problems in industries and enterprises. The phenomenon of school teaching and industry being disconnected is serious, mainly due to the fact that the school-enterprise cooperative practical teaching platform has not been established, and the corresponding practical links are relatively isolated and the practical content is relatively scattered, lacking a systematic and scientific practical training system. The integrated experimental and training part is not organically integrated with the major, for example: engineering training only operates on the mechanical part, without targeting typical robot mechanical components; the control object of the PLC course design is still using traditional water-flooding lamp control, and the correlation with robot integration application technology is relatively low [23,24]. Industrial robot teaching programming and operation, as the main comprehensive practical content, due to objective factors, students did not participate in the training of robot disassembly and control system debugging, thus lacking intuitive cognition of the mechanical structure characteristics of the robot and not having a deep understanding of the robot's control system and function [25-28].

3.   The Methods for Reforming the Industrial Robot Professional Education-Innovation Integration Courses to Adapt to Regional Industrial Development

(1) The country should formulate management standards for personnel involved in the research and development of industrial robots. Although vocational colleges in our country have already offered relevant professional courses

on the research and development of industrial robots, the parents of current students have not highly recognized these courses. Therefore, there is still a great difficulty in cultivating professionals in this field. In response to this phenomenon, the country should first attach great importance to the implementation of such courses and vocational colleges should focus on cultivating industrial robot research and development talents, respecting technical talents. At the same time, the country should implement the "double certificate system" for different levels of schools, and grant two degree certificates to students who study such industrial robot research and development courses. Due to the different teaching quality of different levels of schools, schools should implement a system of step-by-step teaching for students of different levels. At the same time, attention should also be paid to the management of teaching models within the school, not only strictly managing students' professional skills and knowledge, but also strictly controlling other basic cultural courses for students of vocational colleges to ensure the formation of students' basic cultural literacy. The realization of the above process requires the country to formulate a national management standard for training professional skills talents and adopt scientific and reasonable methods to manage industrial robot professionals.

(2) Vocational skill schools should adopt appropriate teaching models. The industrial robot major is relatively abstract and complex compared to other majors in vocational schools. Therefore, for this major, if students do not have a good cultural foundation, the learning of skills in this major will be much more difficult. So, if vocational schools want to change this predicament, the school itself should innovate and change the teaching model of this major course. The teachers teaching the professional courses should adopt appropriate and reasonable teaching methods in the classroom, converting the specific and abstract theoretical knowledge of industrial robots into easily understandable knowledge points to teach students, and at the same time, they should pay attention to the cultivation of students' practical operation ability and effectively realize the integration of industry and education in industrial robots.

(3) Reform the teaching mechanism. Currently, most vocational schools in China have kept up with the times and adopted modern teaching management models, paying more attention to the close combination of theory and practice of students. In order to increase the interest of students in learning professional courses in the industrial robot major, the school should reform its teaching mechanism and adopt new forms of teaching. For example, adding competition content during the teaching process, allowing students to improve their interest through competitions and enhance their learning of the industrial robot major courses.

4. The Construction of the Curriculum System Integrating Education and Industry

Connect the robot industry chain and innovation chain, and establish a theoretical course system oriented towards the market and industry demands in the field of industrial robots, as well as a practical course system covering innovation and entrepreneurship education. Among them, the credit ratio of practical courses reaches 28.03%, ensuring that students have sufficient time for practical operations and project practices.

1. A progressive theoretical course system that integrates multiple disciplines through "category + module" approach.

   The theoretical courses are divided into five modules based on categories: general education courses, engineering foundation (basic disciplines foundation), professional foundation, professional courses, and comprehensive courses. Courses are set up in four stages from the first year to the fourth year.

   The first stage is the robot cognition stage, mainly featuring general education courses such as advanced mathematics, English, physical education, moral education, labor education, mental health, career planning and innovation and entrepreneurship education. These courses are indispensable for cultivating well-rounded talents and providing essential methodologies for further learning. At the same time, some engineering foundation courses such as university physics, C language and engineering graphics are combined to stimulate students' interest in professional learning.

   The second stage focuses on consolidating the mechanical and electrical foundation of robots, mainly covering professional basic courses such as mechanical design fundamentals, electrical and electronic technology, control engineering fundamentals, single-chip microcomputer principles and applications, and signal analysis and processing. It also combines engineering basic courses like complex function and integral transformation, engineering mechanics, and professional English. The main goal is to cultivate students' basic qualities and professional knowledge for the robot industry, laying a solid foundation for their career development and lifelong learning.

   The third stage is the professional course enhancement stage, which focuses on robot mechanism and structure design, strengthens drive and control technologies, and offers courses such as machine vision and application, artificial intelligence and machine learning algorithm design, providing a basis for improving the intelligence level and autonomous decision-making ability of robots. Courses in electronic and electrical control such as

sensors and testing technology, PLC principles and applications, embedded systems, hydraulic and pneumatic transmission, and mechanical transmission control help achieve precise motion control of robots.

The fourth stage strengthens the construction of comprehensive professional courses, with a focus on setting courses such as robot system integration and application, and mobile robot positioning and navigation. It highlights the directionality and cutting-edge nature of professional elective courses, aiming to enable students to comprehensively apply their professional knowledge and solve problems in robot system integration and application development.

2. Multilevel and three-dimensional practical course system.

The cultivation of the ability to solve complex engineering problems serves as the basis for the establishment of practical courses, and a multi-level and three-dimensional practical course system is constructed by networking different levels of practical sections, integrating with science and technology competitions, research projects, and innovation training, etc. The practical courses include four levels: engineering basic practice, professional basic practice, comprehensive training practice, and innovation training practice. They are combined with theoretical sections and delve progressively from aspects such as robot cognition, operational foundation, application, system design and innovation.

In the first year of university, it is the introductory stage, and the engineering basic practice courses cover the basic disciplines of engineering, mainly including general education experiments and engineering basic experiments (university physics experiments, computer programming design basic experiments, engineering graphics, etc.). At the same time, through science and technology competitions, students' professional learning interest is stimulated.

In the second year of university, it is the consolidation stage, and the professional basic practice courses consist of professional basic experiments (electrical and electronic technology experiments, electronic circuit CAD experiments, Python programming experiments, etc.), electrical and electronic-related practical training (electrical internship, EDA technology training), professional internship (engineering training), and control basic course design (single-chip microcomputer and interface technology course design). Through experiments and practical projects, students' professional basic abilities are exercised. At this stage, students already have certain professional foundations and are the main force in various competitions.

In the third year of university, it is the strengthening stage, by comprehensive training practice, the software programming and development ability is strengthened, and students are trained to write robot low-level driver programs, develop upper-layer application software, and design human-computer interaction interfaces. It includes professional comprehensive experiments (sensor and testing technology experiments, industrial robot programming experiments, robot three-dimensional modeling and simulation experiments, etc.), professional internship (production internship), robot design course design (mechanical design foundation course design, robot system comprehensive design), and robot drive and control training (electrical control and PLC training, robot drive and motion control training). In addition, through participation in science and technology competitions and research projects, students' comprehensive practical abilities can be further enhanced.

In the fourth year of university, the innovation training practice level mainly includes professional comprehensive training, mechanical innovation design, and graduation design. The relevant training contents mainly come from science and technology competitions, innovation training projects, and research projects. Through projects that are close to engineering practice and the frontiers of scientific research, students' comprehensive application ability of knowledge is further improved.

5.   Course Teaching Implementation Measures and Outcomes

Attach great importance to the collaborative education work between schools and enterprises, jointly build school-enterprise cooperation courses, online and offline course resource libraries and experimental teaching platforms. Through implementing classroom teaching reforms and establishing multiple evaluation indicators, etc., enhance students' autonomous learning ability [29,30].

(1) Construction of robot hardware and software platforms The school has newly built a robot comprehensive training room and a robot virtual simulation experiment center in the past two years. It has equipped with high-end training equipment, including collaborative robots, basic teaching workstations and typical process application workstations, providing students with practical learning resources and platforms. Using projects as the carrier, students carry out practical exercises and innovative practices, which has stimulated their learning interest and promoted the improvement of their practical abilities.

(2) Implementing the collaborative education mechanism between schools and enterprises. Relying on the first robot modern industry college in Henan Province, deepen the cooperation between schools and enterprises, actively collaborate with the Jiangxi Institute of Mechanical Science, Xintong Machinery, and Shenzhen Yujiang Technology Co., Ltd., etc., by jointly establishing internship bases and laboratories. Five enterprise-partnered

teachers were introduced to guide practical teaching such as engineering training, production internships, and graduation design. The graduation design topics were selected from real projects and cases of enterprises, and joint participation in academic and scientific competitions was carried out. These measures have stimulated students' innovative consciousness.

(3) Pilot academic mentorship system. In 2021, the School of Electronics and Electrical Engineering of our university piloted the implementation of the academic mentorship system for the first time. Professional teachers served as academic mentors, providing academic guidance to 5 to 10 students starting from the first year of study, and leading them to participate in academic competitions or research projects. In the past two years, the mentors have guided students to win over 50 provincial-level and above awards in competitions such as the Rui'an Robot Developer Competition, the Internet+College Students' Innovation and Entrepreneurship Competition, and the "Siemens Cup" China Intelligent Manufacturing Challenge.

(4) Promoting the construction of teaching resources for core professional courses. Engage in school-enterprise cooperation in course development, create high-quality teaching cases, jointly build a teaching resource library. The teaching team has now developed 3 application-oriented textbooks such as "Electrical Control and PLC Application Technology", and has undertaken 5 research projects on higher education reform in Henan Province, 5 projects of collaborative education and industry cooperation for cultivating talents, 3 first-class courses and courses with ideological and political education demonstration effect in Henan Province, 3 school-level resource libraries, 3 first-class courses at the school level, and 2 enterprise-cooperative courses at the college level.

(5) Implementing blended teaching based on the OBE concept, constructing a diversified evaluation index system for professional practice courses, and strengthening learning process management. The diversified evaluation not only involves diversified evaluation subjects but also focuses on process evaluation. The assessment of practical course performance is jointly conducted by the teaching staff and enterprise teachers. The assessment indicators include aspects such as classroom discipline, operational ability, innovative achievements, teamwork, and the correctness of problem answers, making the evaluation more objective and more in line with actual work requirements.

6. Conclusion

The construction of an integrated curriculum system for the robotics engineering major in application-oriented universities, which is oriented towards the transformation and upgrading of the manufacturing industry, is an effective way to cultivate high-quality talents who can meet the demands of the manufacturing sector. By considering the positioning of talent cultivation, establishing training goals and graduation requirements based on industry needs, and using the OBE (Outcome-Based Education) concept to design the theory and practice curriculum system, through school-enterprise cooperation to jointly build online and offline resource platforms, practical teaching bases, strengthen the faculty and improve the evaluation, it is possible to provide students with a better teaching environment and resources, improve the quality of talent cultivation, and inject new vitality into the transformation and upgrading of the manufacturing industry. However, the construction of the curriculum system is not a one-time task; it needs to be continuously improved and optimized to adapt to the constantly changing demands of the manufacturing industry.

7. Conflict of Interest

The authors declare that there are no conflict of interests, we do not have any possible conflicts of interest.

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