Exploration of Diversified Major Practice Course System

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Abstract. In response to the new demands for talent cultivation in automation under current circumstances, reforms have been made to major practice course. These reforms include expanding diversified practice methods and approaches, constructing multi-purpose composite on-campus and off-campus practice and training bases, improving the course evaluation system and process management mechanism, and building a full-cycle automation major education practice course system centered around this course. The goal is to cultivate students into high-quality, high-level innovative talents to meet the societal needs for industrial upgrading and technological innovation.

Keywords: Diversification, Major Practice, Innovative Education, Full-Cycle Cultivation.

1 Introduction

Major practice is an indispensable and crucial practical teaching component of the Automation major. However, with the implementation of the national innovation-driven development strategy and the continuous upgrading of the global industrial structure, as well as the exploration and advancement of first-rate universities and disciplines [1], the objectives and content of major practice are also evolving continuously.

After the 21st century, the problem of lack of engineering ability and innovation ability cultivation in undergraduate teaching system has become increasingly prominent around the world. The paradigm of higher engineering education represented by Franklin W. Olin College of Engineering has been paid more and more attention, and its educational concept of inquiry learning around curriculum projects and deep integration of production and teaching is being accepted and tried out by more countries and universities [2-5]. Meanwhile, a series of guiding documents supporting college students' innovation and entrepreneurship, integration of industry and education, and cooperation between schools and companies issued by the State Council, the Ministry of Education, and other ministries [6-9] have provided direction for undergraduate major education, focusing on cultivating undergraduate students' ability to solve complex engineering problems, fostering innovation and research thinking [10-11]. This ensures that students become high-quality, high-level innovative talents capable of meeting societal needs for industrial upgrading and technological innovation.

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The existing major practice provide students with in-depth company engineering and technical training through various practice modes, such as visits, training, technical seminars and others, as well as the management process of the. This enables students to gain practical production experience and deepen their understanding and application of the theoretical knowledge they have learned in class, laying a solid foundation for their future careers. However, there are also a series of problems: companies do not pay enough attention to college student internships; the internship mode lacks attraction, and students have low enthusiasm for internships; universities often adopt a centralized internship mode, which often emphasizes form over content.

However, for the training objectives of first-rate universities and disciplines, the traditional form and positioning of major practice courses are very limited in terms of cultivating engineering ability, innovative thinking, R&D management ability, and communication and teamwork skills [12]. This makes it difficult to meet the practical teaching requirements and match the curriculum system, thus failing to support the achievement of the major training objectives and graduation requirements. Therefore, the Automation major has designed a new course, "Innovative Practice," to enhance the role and function of major practice. The course satisfies the engineering technology training requirements of major practice while reforming the content and teaching methods, practice and training base construction, evaluation system, and process management, as well as the major education practice curriculum system.

2 Diversified Major Practice Course Construction

The major employs scientific research and competitions as means, projects as carriers, and implements the mentorship for undergraduate studies. It adopts a step-by-step practical form, diversified course practice methods, and project-based learning content derived from actual needs.

1) Practical course construction is carried out through a multi-level practice format characterized by "broadening horizons, major competitions, undertaking projects, and pursuing innovation." This format progressively cultivates students' scientific research and innovative thinking. Through campus research laboratory visits, excellent company visits and lectures, and excellent alumni return visits to their Alma mater for exchange, students are encouraged to actively participate in major competitions, do some exploratory experiments, design practical exercises or other scientific and technological innovation activities, and then join the tutor's research group to carry out some scientific research projects. Make them realize the sense of achievement of applying what they have learned, improve the thinking and consciousness of independent creation, and have a strong interest in learning.

2) Considering the training objectives and capability requirements, and in conjunction with the different training needs for various career paths after graduation, the course expands the methods and means of major practice. Students can achieve practice requirements through internships at related companies, participating in science and technology innovation competitions, practice in projects at domestic and foreign universities and research institutes, and other research-related experiences.

Additionally, the completion cycle of the course content has been extended, with course introductions beginning in the first or second year of study. This early start helps students prepare for the course in advance and also encourages them to plan their college careers earlier. Furthermore, all competition and research practice activities that have not been recognized for innovation credits in the first three years are now included within the scope of course credit recognition. This encourages students to make full use of each summer semester, winter and summer vacation time to engage in scientific research and competition activities lasting no less than one month.

3) Setting Practice Content Based on Actual Needs. According to statistics, since the enrollment of undergraduate students in our Automation major, the rate of further education upon graduation has consistently exceeded 60%, meaning that students actually do not have sufficient time to invest in their graduation projects, leading to overall quality that does not meet expectations. The course encourages students who choose laboratory internships to combine their internship with graduation project topics, starting preparation half a year in advance, thereby enhancing the quality of undergraduate graduation projects.

Students opting for company internships can also select projects closely aligned with the actual needs of the company under the guidance of dual tutors (both a university tutor and an company tutor). They can connect the content of their graduation projects with these projects and continue to complete their graduation projects at the company during the second semester of their fourth year.

4) Implementing an Undergraduate Academic Tutorial System to Cultivate Students Holistically and Personalized. Starting from the first year, the major implements an undergraduate academic tutorial system. Academic tutors guide students' career planning, strengthen their moral character and overall quality, stimulate their passion for learning, foster a rigorous and pragmatic academic style, assist students in formulating personalized study plans, ignite their interest and awareness in research, and guide them in engaging in research work, academic competitions, social practices, entrepreneurship, and innovation activities. This approach aims to cultivate students' innovative consciousness and practical abilities.

3 Construction of Multi-Purpose Composite On-Campus and Off-Campus Practice and Training Bases

Using projects as a means and relying on on-campus and off-campus practice and training bases as well as platforms for scientific research and innovation, students are given the opportunity to experience a relatively complete process of research and development as well as management. Based on existing scientific research platforms, a specialized on-campus training base has been established that integrates "teaching, competition, innovation, research, and testing," continuously improving and enhancing students' practical and application skills. At the same time, efforts are being deepened to promote the integration of industry and education, actively carrying out collaborative talent cultivation work between universities and companies. Twelve off-campus practice and training bases have been established, engaging in various forms of industry-university-research cooperation and exchange. This aims to build a new type of regional innovation system, promoting the interactive benefits and cooperative sharing of knowledge, technology, and human resources.

1) Integration of Research and Education, Continuously Improving the Construction of On-Campus Practice and Training Bases.

Relying on the Shenzhen Branch (under preparation) of the State Key Laboratory of Robotics Systems and Technology, 2 provincial key laboratories, and 7 municipal scientific research platforms, the major has specifically purchased 126 sets of equipment and instruments, totaling 24.86 million yuan. These resources have been used to jointly establish a “Creative Robotics Innovation and Entrepreneurship Service Platform,” supporting four open-ended practical teaching courses for undergraduates and postgraduates across multiple majors. The platform also serves the needs of faculty and students for competitions, innovation, research, and testing. Through project-based teaching, the program focuses on three main cultivation directions: control theory and control engineering, robotics and intelligent systems, and intelligent detection. This enables students to master practical skills in control system analysis and design, research and development, integration and operation, management, and decision-making. Ultimately, the program aims to develop students' comprehensive abilities in scientific research, technology development, technical management, and innovation and entrepreneurship in the field of automation and related areas.

2) Industry-Education Integration, Building an Open Industry-education Innovation Ecosystem.

Drawing on the model of the "Outstanding Engineer Training System across Undergraduate and Graduate Levels" at the main campus of Harbin Institute of Technology [13] and leveraging the geographical advantages of the Greater Bay Area where the Shenzhen campus is located, the major has initiated the construction of a new industry-education innovation ecosystem. As of September 2024, agreements for off-campus practice and training bases have been signed with more than ten companies, including Googol Technology, DJI Innovations, Songshan Lake International Robot Base, RoboSense, DOBOT, LEJU Robot, INOVANCE, and Leadshine, among others. Long-term cooperative relationships have been established in areas such as visitation internships, lecture training, internal exchanges, talent cultivation, industry-education collaborative talent development, and technical cooperation projects.

4 Construction of a Diversified Course Evaluation System and Process Management Mechanism

Aiming at the learning outcomes of students, the course evaluation is conducted using various methods, emphasizing the combination of process and results, and fully leveraging the role of evaluators. Using innovation projects as a vehicle, a diversified course evaluation system and process management mechanism have been established to comprehensively and accurately assess students' engineering capabilities, innovative thinking, R&D management abilities, and communication and teamwork skills.

1) Summarizing the implementation of courses in recent years, detailed rules for recognizing and managing independent practice and scoring guidelines have been formulated. These rules serve as a refinement and supplement to the undergraduate practice teaching management system of the campus. They clarify the scope of practice, methods of implementation, specific content, practice goals, and requirements within the course. Further, they standardize the responsibilities and procedures of relevant personnel and departments during practice, and outline detailed process management, assessment, and summary content. Students' overall qualities and abilities are evaluated from multiple dimensions, including "moral character, literacy, attitude, capability, innovation, collaboration, and achievements."

2) A diversified evaluation system involving multiple stakeholders has been established to improve the process monitoring of the execution effectiveness of practice teaching work. This system incorporates evaluations from students, university tutors and company tutors, course instructors, and companies. The course includes student self-assessments and evaluations by practice supervisors in the practice report. Weekly summaries and reports are also used as important references to measure the planning and execution of practice, supplemented by periodic mentor communications and feedback on learning situations, forming a diversified evaluation framework for multi-dimensional assessment.

Regular visits and follow-up surveys after course were conducted for students from the Automation major of the 2019-2021 cohorts. A total of 138 anonymous survey questionnaires were collected. The survey covered five main aspects: course objectives, experimental content and capability enhancement, practice training and organization, practice guidance and environment, and evaluation and feedback. Among the survey results, 59.42% expressed very high satisfaction with the new course, while 34.78% indicated satisfaction.

Students were also invited to provide feedback on the direction of curriculum reform and the professional practice teaching system, yielding over 30 valid feedback items. Some of these suggestions have been incorporated into the revision of the new professional training program and the content of practice courses. This ongoing process gradually refines the standards for professional practice training and promotes effective measures and methods. By implementing these changes, the course continuously improves itself within this closed-loop process control management, forming a virtuous cycle.

3) In the joint training management between the university and company, the "PDCA" concept [14]—which stands for Plan, Do, Check, Act—has been introduced. This concept emphasizes four key elements: people, quantity, responsibility, and methodology. It clarifies the specific requirements and process management system for joint training, transforming inspections into "services" to promptly summarize and solve the issues, continuously refining the training standards, and proactively forming a virtuous closed-loop management system. For problems identified during the training process, management measures are implemented to coordinate and control them. For potential issues that may arise later, guidance is provided to resolve them, thereby effectively enhancing the quality and outcomes of the joint training program between the university and company.

5 Construction and Improvement of a Full-Cycle Automation Major Educational Practice Course System

The structure of the undergraduate student training course system in Chinese universities is constrained by the drawbacks of a hybrid Soviet and American model, leading to a series of issues such as an excessive number of courses, short durations, and scattered content. These problems make it difficult to achieve deep learning that integrates theory and practice [15]. Our university has undertaken some effective reform attempts in the core courses of the Automation major [16], and these reforms have been promoted across the three campuses. Additionally, we are undergoing reforms in the enrollment system for broad categories of majors. However, the aforementioned issues still persist in the practical teaching system.

To this end, the major has constructed a full-cycle major education practice course system spanning four years. This system uses the "Innovative Practice"courses as a pivot to connect the dots, helping students consciously plan their undergraduate academic careers. By linking all practical major education courses through the concept of "Robotics and Intelligent Systems".

The major education practice course system is built on two mandatory practical courses: "Robot Design and Practice" and "C Language Programming Course Design." These courses serve as the foundational hardware setup and software programming basis for the students' practical teaching system. Under the guidance of undergraduate academic mentors, the "First-Year Annual Project," which covers all our major students, acts as a critical support for academic competitions. By aligning project content with course requirements, effective project iterations are conducted.

For example, using the Arduino-based autonomous line-following wheeled robot from the "Robot Design and Practice" course as a platform, additional functionalities such as automatic obstacle avoidance, gesture control, mobile robotic arms, and visual recognition are added as content for the "First-Year Annual Project." These projects are then appropriately upgraded according to competition needs to participate in relevant academic competitions. Through two to three years of iterative improvements, the system aims to achieve breakthroughs in competition results and the cultivation of engineering practice skills.

Competitions are a highly supported form of practical activity by both the university and the major, and they align very well with course requirements. They are activities that can match the employment or further education goals of all graduates. Therefore, the course team is actively promoting students' participation in competitions. The course team has categorized key competitions related to postgraduate recommendation and national scholarship reviews in the Automation major into three levels: A, B, and C. Students participate in these competitions at different levels based on the course content and annual projects.

•A-Level Competitions: These include the national-level stages of the "Three Major Competitions" (the China College Students' “Internet+” Innovation and Entrepreneurship Competition, the "Challenge Cup", and China College Students' Entrepreneurship Competition), as well as ROBOCON, RoboMaster and RoboTac. It is recommended that 5% of students participate in these competitions.

•B-Level Competitions: These include the provincial-level stages of the "Three Major Competitions" and other robot and artificial intelligence competitions. It is recommended that 50% of students participate in these competitions.

•C-Level Competitions: These include the internal selection stages of the "Three Major Competitions" and other competitions such as mathematics, english, electronic design, automation, and mechanical innovation design. It is recommended that all students participate in these competitions.

In the last three course cycles, the competition participation rate of students from the Automation major in the 2019-2021 cohorts has significantly increased. The credit recognition rate rose from 33.7% to 79.1%, indicating that at least 80% of the 2021 cohort participated in discipline-related competitions and achieved excellent results. Among these, the proportion of students winning awards at the national level or above reached as high as 78.6%. In recent years, students from the Automation major have successively won the first and second prizes in the national ROBOCON competition, the championship in the RoboMaster for two consecutive sessions, and the championship and runner-up in the VEXU Competition at the Chinese Selection of the 15th VEX Asian Robot Championship. Both the quantity and quality of their achievements have seen significant improvements.

6 Conclusion

In response to the societal demand for talent in automation to support industrial upgrading and technological innovation, the course team has initiated a diversified professional practice course construction effort, starting from the course level. This initiative has expanded the diversity of course practice methods and approaches, established a number of excellent multi-purpose composite on-campus and off-campus practice and training bases, and developed a diversified course evaluation system and process management mechanism. And try to connect the cognitive practice and introductory course content forward into the graduation project backward, significantly increasing students' participation in competitions.

This has led to the construction of a full-cycle major education practice course system for the Automation major. The system effectively enhances students' initiative in participating in scientific research and innovation activities, fully leverages the core functions of on- and off-campus practice and training bases, and promotes the diversified and innovative development of practice teaching. Ultimately, this better meets the national strategic needs and regional demands for high-level practical talent in the field of intelligent systems, as well as the need for scientific research, engineering, technology, and management personnel in enterprises and institutions.

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