The Research and Practice of "Bidirectional Integration, Multi-Dimensional, and Overall" Intelligent Manufacturing Talents Training Mode

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Abstract: As our nation continues progressing toward becoming a leading manufacturing powerhouse, the demand for skilled individuals in intelligent manufacturing is rising. However, there are current issues with these individuals' knowledge systems, practical ability, and core quality cultivation. In response, we have developed a comprehensive 'Bidirectional integration, Multi-dimensional, Overall' talent training model designed to produce top-tier applied intelligent manufacturing engineering professionals. Through our continuous efforts and experimentation, we have achieved remarkable success in cultivating exceptional talent.

1. Introduction

“Made in China 2025" defines the overall strategy of China's construction of a manufacturing power at the national level, with the promotion of intelligent manufacturing as the main direction of attack, and realizes the historical leap of the manufacturing industry from big to vigorous. With the continuous transformation of industrial upgrading, enterprises’ demand for high-quality intelligent manufacturing engineering and technical talents is increasing daily. In this situation, universities should actively adapt to social development needs, timely adjust training strategies, optimize training models, continuously improve the quality of talent training, and provide many high-quality applied intelligent manufacturing engineering and technical talents for society[1].

2. Analysis of the current situation of intelligent manufacturing talent cultivation

Facing the needs of the intelligent manufacturing industry, universities have launched the upgrading and transformation of traditional majors and the construction of new engineering majors. The core majors of new engineering are "intelligent manufacturing engineering" and "robot engineering.” Due to their short development history, they have yet to reach the mature stage of development and lack talent training experience, resulting in the quality of intelligent manufacturing talent training at this stage being low, and there are several problems.

2.1. There needs to be more connection between the structure of professional knowledge and the job requirements of enterprises

The frequency of on-the-spot investigation is low, and the communication still needs to be more profound. The knowledge about the position setting of the enterprise is not enough, especially the knowledge content system required by the post is not enough, the talent training plan lags behind the industry development, and the method of professional courses is still based on the needs of traditional industries and out of touch with the requirements of enterprises.

2.2. The efficiency of collaborative education between schools and enterprises is low

Although the cooperation between colleges and enterprises has been carried out for many years, some things could be improved, such as the unsound cooperation mechanism, the unbalance between the demand for talent in enterprises and the supply of schools, etc. As a result, school-enterprise

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cooperation needs to be more in-depth and careful, coverage needs to be more comprehensive, many works are floating on the surface, and collaborative education needs to be higher efficient.

2.3. The training system of engineering practice ability could be better

Engineering practice ability is one of the important indexes to measure the practical application ability of students, and the cultivation of functional capacity is the crucial work of talent cultivation in colleges and universities; the practice teaching system is not perfect yet; the proportion of enterprise engineering practice teaching is small, the majority of teachers in the teaching staff are young, and most of them are from university graduation to university employment, and lack of enterprise practice training, it is challenging to meet the needs of enterprises because of the weak ability of engineering practice.

2.4. Single solidification of talent training method

Higher requirements have been put forward for intelligent manufacturing talents in new engineering. Students should learn interdisciplinary knowledge and have comprehensive solid analysis, solution, and innovation abilities. At this stage, the talent training method of most colleges and universities is relatively simple, either academic research-oriented or practical application, which restricts the diversification and personalized development of students to a certain extent.

2.5. The imbalance between intellectual and moral education

It is an essential mission for colleges and universities to adhere to and carry out the fundamental task of "Setting up morality and cultivating people." much work has been done in cultivating core qualities such as "Strengthening ideals and beliefs, cultivating patriotic feelings, strengthening moral cultivation." Still, it has not been carried out in-depth, the proportion of core quality training is too small, and the imbalance between academic and moral education is profound.

3. Ideas and measures for the cultivation of intelligent manufacturing talents

In response to the current need for intelligent manufacturing talent development, we are dedicated to cultivating students' engineering skills, innovation, entrepreneurial abilities, and core competencies through a 'double integration, diversification, and overall' training model. 'Double integration' entails close collaboration between schools and enterprises to foster innovation and integration. 'Diversification' involves comprehensive coverage of ideological and political courses, complemented by a 'studio + personalization + internationalization + engineering + core quality' multidimensional talent training. 'Overall' refers to the establishment of a dynamic regulatory mechanism, which includes regulating emotional aspects of talent training programs, teaching resources, and quality assessment. We aim to continuously optimize and improve the talent training system[2], ensuring the highest quality of training for our students.

3.1. Match job requirements and optimize the curriculum system.

All majors should conduct two comprehensive enterprise researches per semester, understand the workplace environment in depth and establish the connection between job roles and course materials, determine the training objectives for intelligent manufacturing engineering professionals, cooperate with industry partners, improve talent development plans, reform courses, and build an integrated "platform + module" interdisciplinary system, integrate the basic technical knowledge of intelligent manufacturing to keep up with the requirements of industrial development.

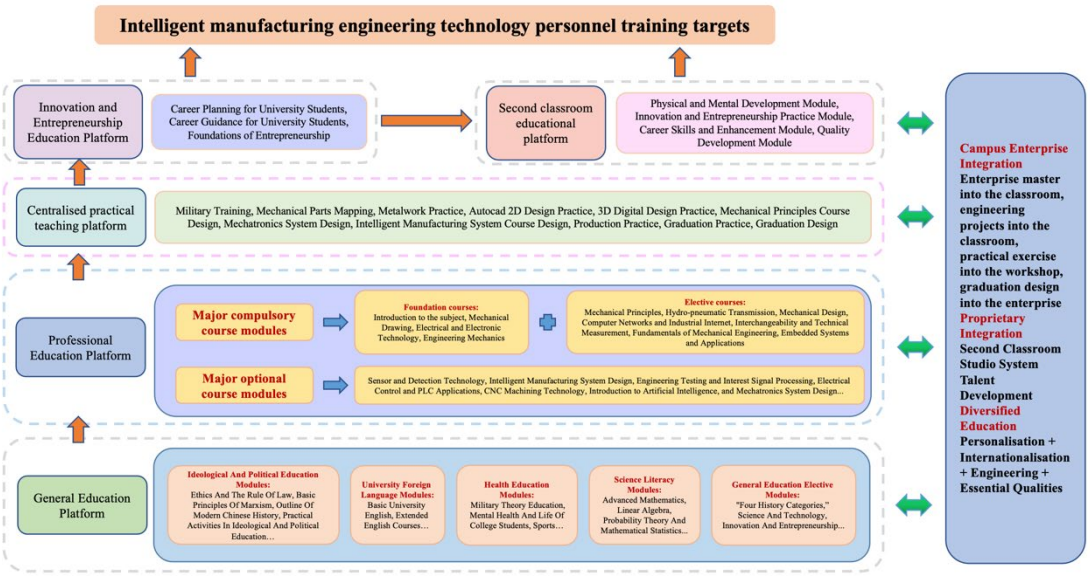

Figure 1 Intelligent manufacturing engineering technology personnel training objectives

3.2. Relying on industry colleges, deepening cooperation between schools and enterprises

Relying on the modern industrial college of intelligent manufacturing in Shandong Province and the school-level robotics industry college, we have built a "double helix" school-enterprise in-depth integration mechanism based on the "double helix" structure of DNA. Horizontally, it maintains stability through cooperation agreements and training of order classes. Vertically, stability is maintained through joint technical research, talent training, and transfer. The management mode of co-construction, co-management, co-education, and sharing is implemented. An effective means of enhancing school-enterprise cooperative education lies in the implementation of the 'Four in' model. This model involves integrating enterprise experts as educators, incorporating engineering projects into the curriculum, providing practical exercises in workshops, and involving the enterprise in graduation design. This approach cultivates a mutually beneficial relationship between the school and enterprise, fostering extensive cooperation between the two. To achieve this, a matrix education model that is diversified, comprehensive, and all-encompassing should be devised to facilitate comprehensive school-enterprise collaboration[3].

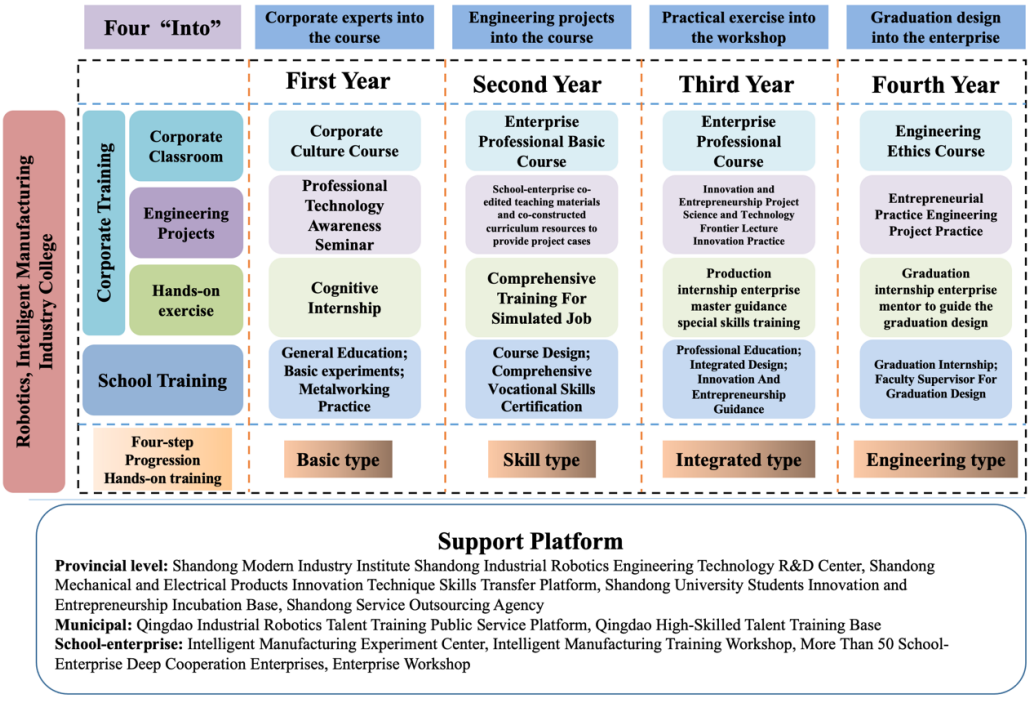

Figure 2 The "Four into" school-enterprise cooperative education model

3.3. Building a platform for dual innovation and promoting the integration of specialization and innovation

The university and enterprises have jointly built eight science and technology innovation studios, such as robotics and intelligent equipment[4], facing the current situation that society is in great demand for innovative talents. A three-teacher team of "double teachers + innovation and entrepreneurship tutors + enterprise tutors" has been established. We have found a "standardized, institutionalized, and normalized" incentive mechanism for cultivating innovative and entrepreneurial talents by providing joint guidance in dual-innovation projects, science and technology competitions, and graduation designs. Students are encouraged to engage in innovation and entrepreneurship, and teachers are motivated to engage in dual-innovation activities. We have reformed the talent training program and integrated the cultivation of innovation and entrepreneurship into the graduation requirements and training objectives. A curriculum system has been built to promote innovative talents. A series of courses on innovation and entrepreneurship have been set up on various platforms, including general education, professional education, practical education, and the second classroom.

The objective is to establish a comprehensive training system with three main components: integrating competition projects into teaching materials, incorporating competition facilities into teaching resources, and enhancing the theoretical and practical teaching abilities of educators, along with fostering the analytical, problem-solving, and innovative skills of students. For instance, the Advanced Drawing Technology and Product Information Modelling Innovation Competition for University Students are seamlessly integrated into the courses of Mechanical Drawing and 3D Digital Design. Similarly, the National Mechanical Innovation Design Competition for University Students and the Mechanical and Electrical Products Innovation Competition are embedded into the Mechanical Design system. The CNC Simulation of Intelligent Manufacturing Competition for University Students is implemented in the CNC Machining Technology course, while the Robotics Series course encompasses the Intelligent Robot creativity competition, intelligent manufacturing competition, and other projects.

Simultaneously updating equipment, fostering competition, and mutual teaching are crucial elements in promoting learning. Integrating competition assessment into teaching evaluations by incorporating industry standards and specifications into daily teaching and training is essential. Furthermore, the cultivation of professional ethics and professionalism should be incorporated into the evaluation process. This comprehensive assessment reflects students' quality, knowledge, and ability. By integrating these three aspects, competition can enhance teaching and learning, broaden the scope of students benefiting from competition, and foster an atmosphere of innovation and entrepreneurship, thereby enhancing the overall innovation ability of students. Through the establishment of a mechanism integrating specialization and innovation, students' innovation and entrepreneurship abilities can be progressively developed, moving from 'innovation awareness → innovation ability → innovation practice → transformation of results,' thereby enhancing their innovation and entrepreneurship skills comprehensively.

3.4. Carrying out diversified education to promote overall development

A multi-dimensional approach to personalization, studio, internationalization, and engineering promotes the overall development of students and considers their individual growth needs. The "personalized" training means that from the first year onwards, students will be formed into "innovation classes," "experimental classes," etc., according to their characteristics and personal intentions to meet their individual development needs. The "School-Enterprise Cooperation Classes" are designed to meet the individual development needs of students. The "Studio" training is based on the science and technology innovation studio, the two-way management system of teachers and students, the instructor and the student president are jointly responsible for guiding students to participate in science and technology competitions, host large innovative projects, publish papers and write patents, etc., to cultivate students' innovation and entrepreneurial ability. The "Internationalization" training is aimed at students of mechanical design and manufacturing and automation, intelligent manufacturing engineering, and other majors, dovetailing with international

engineering education standards and cultivating high-end technical talents; the university and enterprises jointly set up the "Excellent Engineer Class in Japan," dovetailing with Japanese intelligent manufacturing-related enterprises. In addition, the university has set up the "Excellent Engineer Class in Japan" to connect with Japanese intelligent manufacturing-related enterprises and cultivate international talents. The "engineering-based" training emphasizes cultivating students' engineering practice abilities. Our school has established partnerships with off-campus enterprises to collaboratively develop a comprehensive curriculum content system and enterprise classrooms. We've crafted teaching resources that seamlessly integrate enterprise projects, and we've actively involved enterprise experts as mentors to guide and instruct our students. Additionally, enterprise tutors have been enlisted to support our students throughout their graduation design process. This collaboration provides our students with exposure to real production scenarios, offering invaluable practical experience that enhances their practical engineering skills.

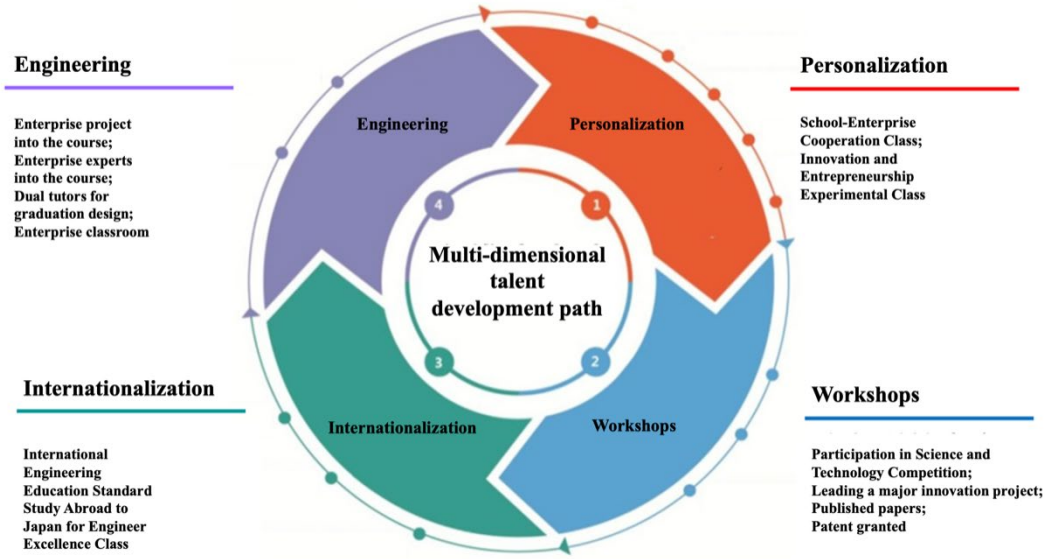

Figure 3 Multi-dimensional talent development pathway

3.5. Implementing Curriculum Ideology and Politics to promote moral competence

Adhering to the fundamental task of "establishing moral education," the university has implemented a comprehensive coverage of curriculum thinking and politics. In general education, professional education, practical education, and the second classroom, we promote the comprehensive reform of curriculum thinking and politics. To address the weakest link in moral education, the professional courses have been revised, and the status of the achievements in the construction of curriculum thinking and politics has been enhanced through the revision of syllabuses and the selection of model courses, model classes, excellent teaching teams, and excellent teaching designs. Encouraging teachers to participate in teaching reforms and incorporating ideological education into the teaching process are crucial. This approach maximizes the classroom's potential as the primary platform for educating students and the community at large. The primary objective is to cultivate students' core socialist values, essential literacy skills, and craftsmanship, resulting in the cohesive development of knowledge, skills, and personal qualities.

3.6. Building a regulatory mechanism to improve the quality of education

To ensure effective and adaptable talent training programs, it is crucial to establish a dynamic control mechanism that encompasses various aspects of the process, including teaching resources, system construction, and quality evaluation. To achieve this, we will adjust our talent training program every 1-2 years, considering the needs of industrial development and upgrading, as well as addressing the employment requirements of enterprises. The construction of teaching resources will be a key focus, aiming for 100% coverage of online courses. We plan to build 5-6 online courses at

the provincial level, co-construct course resources between schools and enterprises, and develop at least five teaching cases/projects for each undergraduate major. Additionally, we will optimize the talent training system by promptly updating our education concept, responding to the demand for talents, adjusting our training strategy accordingly, and continuing to promote the construction of industrial colleges and first-class majors and courses. We will also enhance the quality evaluation mechanism to ensure the highest standard of teaching. For teachers on campus, we will carry out peer evaluation, student evaluation, and supervisory evaluation activities to provide overall feedback on teaching quality and set up a three-tier supervisory team from the university, faculty, and department to carry out lecture listening activities, especially for young teachers and part-time teachers, to continuously improve the overall teaching level of the teaching team. For on-campus students, teachers' and students' mutual evaluation activities are carried out to give full play to students' subjective initiative and increase their motivation to participate in learning. For off-campus employment/internship students, graduate return visits and enterprise evaluations are conducted to promptly track and provide feedback on student performance and adjust training strategies. Through implementing a series of moderation initiatives, the structure of talent training is continuously adjusted, and the quality of talent training is constantly improved.

4. Effectiveness of talent training model reform

The "dual-integrated, diversified, and overall" talent training mode has achieved remarkable results after three years of practice in intelligent manufacturing engineering, mechanical design and manufacturing and automation, robotics engineering, and other majors.

4.1. Outstanding results in talent development

In the past three years, the employment rate of students has remained stable at over 97%, with a professional matching rate of 79%. Employers have praised the graduates for their "excellent professional skills, a strong sense of innovation and ability, ability to quickly adapt to the needs of the workplace and grow into the backbone of the unit."

In the "three tutors" integrated innovation environment of national maker space, innovation, and entrepreneurship incubation base and innovation studio, students have won more than 800 provincial and federal awards in various science and technology innovation competitions, including 76 national awards, more than 700 provincial awards, and one provincial gold award and 11 silver awards in the 2021 "Internet+" Student Entrepreneurship Competition. "Shandong Science and Technology Association has awarded two workshops and four club officers as Two workshops and four club cadres have been awarded the titles of "Excellent Student Science and Technology Club of Shandong Province" and "Excellent Student Club Cadres of Shandong Province" by Shandong Science and Technology Association, and 12 students have been awarded the titles of "China Student Self-improvement Star" and "China Flying Young Scholarship." Twelve students have been awarded provincial and above honors, such as the "China Flying Young Scholarship," "Qilu Most Beautiful College Student," etc.

4.2. The teaching platform continues to improve

The university and enterprises have jointly built four provincial-level platforms, namely Shandong Industrial Robotics Engineering Technology R&D Centre, Shandong Smart Manufacturing Industry College, Shandong Vocational Education Skill Transfer Innovation Platform - Mechanical and Electrical Product R&D and Technology Innovation Platform, Shandong Higher Education Characteristic Laboratory - Marine Intelligent Equipment Manufacturing and Measurement and Control Technology Laboratory, and Qingdao Industrial Robotics Talent Training Public Service Platform and Qingdao High-Skilled Talent Training Demonstration Base. By constructing the three-level talent training practice platform of "province-city-university-enterprise," we have continuously broadened the channels of practice cultivation and enriched the carrier of practice cultivation. By building a three-level talent cultivation practice platform of "province-city-university-enterprise," the media of practice cultivation are constantly widened, and the airline of practice cultivation is enriched.

4.3. School-enterprise cooperation in full swing

Each major will add at least one new cooperative unit each year and establish a profoundly collaborative relationship, with comprehensive cooperation in significant construction, talent training program revision, curriculum construction, mutual employment of talent teams, practical teaching, graduation design guidance[5], etc. More than 100 part-time teachers from enterprises will be employed by the school, with 96.6% of full-time teachers having an enterprise background and more than 90% dual-teacher type, and 96.6% of teachers will go to enterprises for on-the-job training. In 2022, 12 new cooperative enterprises will be added, all undergraduate majors will have 100% coverage of school-enterprise cooperation, 14 enterprise classes will be taught, 30 teaching cases will be developed, and five teaching materials will be used developed. Ltd. to train outstanding engineers in Japan for 75 students, conduct enterprise training, teach 32 courses by enterprise lecturers each semester, conduct expert lectures four times, and grant scholarships to 16 outstanding students.

Fig. 4 School-enterprise cooperation textbook

4.5. Outstanding results in curriculum development

Based on the course team, we have made great efforts to promote the construction of the courses with remarkable results. Five courses, such as "Fundamentals of Robotics," have been approved as provincial first-class courses; two methods, such as "Mechanical Design," have been approved as provincial model courses in thinking and government; two systems, such as "CNC Machining Technology" have won 2 third prizes for excellent cases of online teaching in Shandong Province, five courses such as "Principles and Applications of Microcontrollers" have had their typical issues of online education included by Super Star. The provincial curriculum alliance platform has made over 16 courses available, one of which is the 'Principle of Machinery.' More than 100 colleges and universities have benefited from these courses, with over 20 million visits. The online course, 'Playing Industrial Robot,' has been recognized as a high-quality offering by 'Learning Power' and has been awarded the third prize for 'Excellent Shared Course' by the Shandong University Curriculum Union.

4.6. Continuous output of teaching and research achievements

The classroom teaching revolution has been promoted, and the proportion of classroom teaching reforms such as hybrid, project-based, and work-process oriented has reached 75.6%. In the past three years, six provincial-level teaching reform projects have been approved, 28 at the municipal and departmental levels, more than 50 papers on education and teaching have been published, and more than 30 monographs and textbooks have been written. Teachers participated in the provincial teaching innovation competition and won one second and three third prizes. They also participated in the National Graphics and Mechanics Curriculum Innovation Competition's second and third prizes, the National Teaching Metaverse Digital Technology Innovation Competition, and three awards of the National Teaching Metaverse Digital Technology Innovation Competition for university teachers.

4.7. The scope of services is broad

Qingdao Huanghai University has successfully organized and hosted several noteworthy academic events at the provincial level. One of these events is the widely acclaimed Taishan Science and

Technology Forum, which has collectively enriched the lives of over 14,000 students. Moreover, the university has served as the gracious host of the Shandong University Student Mapping Competition, where more than 2,000 students from 86 universities were able to participate. The university has also conducted numerous teacher training activities, including the impactful "30 Printing & Smart Manufacturing" program, which has positively impacted 25 universities. The training courses for enterprises such as SAIC-GM-Wuling have benefited more than 4,000 employees. The training courses for universities such as the Ocean University of China have helped more than 2,500 students, thus complementing the resources of enterprises and schools, serving regional economic development, and training high-quality applied talents.

5. Conclusion

By analyzing the problems existing in the training of intelligent manufacturing talents, focusing on the key points such as improving students' engineering practice ability, innovation and entrepreneurship ability and core literacy, we will conduct in-depth enterprise research, optimize the curriculum system, promote school-enterprise integration, specialized innovation and integration, carry out multi-dimensional and meta-education, establish a comprehensive talent training regulation mechanism, and improve the training quality. It has formed a "double-melt, diversified and all-round" talent training model, and achieved remarkable results in talent training.

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