Reform and effects of a training mode for outstanding mechanical engineers

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ABSTRACT: The reform of Chinese higher education has seen changes to curricula, implementation of credit systems, introduction of the dual tutorial system, small classes, individualised teaching methods and strengthening of practice teaching platform, and establishment of joint training through cooperation between colleges and enterprises. From these aspects, the training of outstanding mechanical engineering graduates was approached by Wuhan University of Science and Technology. In terms of curriculum system reform, redundant courses were removed, more appropriate courses were introduced and the content of core courses was refined. In terms of teaching, the preparation of teachers was strengthened and teaching effectiveness was enhanced. The students' practical ability and employability could be strengthened and achieved through joint training programmes with enterprises. With the support of *A Plan for Educating and Training Outstanding Engineers*, a training system has been constructed by the University, and it has cultivated a number of high-quality engineering graduates and technical talent.

INTRODUCTION

In order to adapt to changes in the national economic structure, the structure of graduate training has been changed by the Ministry of Education, and the construction pace of application-oriented talent has been accelerated through *A Plan for Educating and Training Outstanding Engineers* (hereinafter referred to as *Outstanding Engineers*). *Outstanding Engineers* is an important reform programme for implementing the *National Long-term Education Reform and Development Plan Outline (2010 to 2020)*, it is also an important part of the undergraduate teaching project of the Ministry of Education in the period of the *Twelfth Five-Year Plan*.

This plan aims to train a large number of high-quality engineering and technical graduates, who can adapt to the needs of economic and social development and have a strong innovative ability, to provide services for the national strategy of *walking a new type industrialisation road*, building an innovation-oriented country and strengthening China through its graduates' talent. Many scholars have launched extensive and in-depth research on the topic [1-3].

With the support of the *Outstanding Engineers* plan, a road for outstanding engineering training was explored by the College of Machinery and Automation at Wuhan University of Science and Technology based on discipline and the professional advantages, and it is committed to training outstanding mechanical engineers who match the requirements of the era.

Meanwhile, the innovation base of college-enterprise joint training was based on the *College Innovation Ability Promotion Plan* (*2011 Plan*) and the Steel Industry Collaborative Innovation Centre, and focus on the top-level design of the talent teaching mode. The targeted and diversified training mode was implemented to meet the demand of the steel equipment manufacturing industry for the specialisation and internationalisation talents. *The unity of knowledge and practice* and *teaching students according to their aptitude* were stressed to ensure the students comprehensive development, and student individualised development was encouraged. A large number of high-quality engineering graduates with strong innovative ability will be trained through the in-depth reform of the teaching management mode, practice teaching and joint talent training mode, etc.

CURRICULUM SYSTEM REFORM

The *Outstanding Engineers* plan has been designed to train engineering talent mainly in mechanical design, manufacturing, and research and development ability; therefore, the students' practical ability and innovation ability is to be a key part of training students of this discipline. However, the mechanical engineering discipline relates to a range of subject knowledge, and the academic burden is very heavy, which causes the majority of colleges have to come up with more time to undertake the task of teaching. Due to time constraints, students have fewer opportunities to operate

in the practice component, and it is difficult to ensure that students have a perceptual knowledge demand for the mechanical engineering profession. Eventually, the students consider that the courses have no practical value and lead to heavier mental weariness. Therefore, the process of training an outstanding engineer should attach importance to the curriculum reform, redundant courses should be removed, appropriate courses should be set up and the core courses should be refined [4].

The curriculum system under the credit system adopts a flexible system of 3~6 semesters. In the 1st~3rd semesters, students are required to complete the general education platform courses, academic platform courses, professional core courses and basic engineering practice training. At the end of the 3rd semester, according to their personal interest, students can make individual learning plans under the tutor assistance. From the 4th semester, students begin to learn the professional oriented courses, professional optional courses and engineering practice and undergraduate graduation design. In addition, a recognised standard for enterprise internship credits has been established; students are encouraged to take one or two semesters to carry on the full time internship in an enterprise during school time.

The courses for *Outstanding Engineers* training include public basic courses, academic basic courses, professional basic courses, professional oriented courses and practical courses. Among them, public basic courses and academic basic courses are the compulsory curriculum for all students, as shown in Table 1, and professional oriented courses and practical courses as shown in Table 2.

Table 1: Basic courses list.

Course type	Main course
Public basic courses	Ideological and Political Theory, English, Physical Education, Military Theory, Social Practice, Military Training and Computer Application Practice, etc.
Academic basic courses	Mechanical Graphing, Higher Mathematics, College Physics, Theoretical Mechanics, Mechanics of Materials, Electrical and Electronic Technology, Mechanical Manufacture Skill Training, Mechanical Mapping and other practical courses.

Table 2: Featured courses list.

Course type	Main course
Professional basic courses	Engineering Materials, Theory of Machines and Mechanisms, Mechanical Design, Fundamental of Mechanical Manufacture, Technology of Mechanical Manufacture, Control Theory, Fluid Mechanics, Hydraulic Transmission, Measurement Techniques of Mechanical Engineering, Modern Design Method; Cognitive Training, Curriculum Design of Machines and Mechanisms Theory, Curriculum Design of Mechanical Design and other practice courses.
Professional oriented courses	Iron and Steel Production Process Engineering, Smelting Production Process and Equipment, Steel Rolling Production Process and Equipment, Mechanical and Electrical Transmission Control, Mechanical and Electrical Hydraulic System Design.
Practice courses	Metallurgical Equipment Application Training, Enterprise Training.

At the same time, a pilot class for engineering training was established in mechanical engineering, with 30 students a year. The proportion of practice teaching in the teaching plan and curriculum system should be increased. To link theory teaching and practice, the teaching plan and curriculum system should meet the requirements of the coordinated development for students' knowledge, ability and quality; meanwhile, the training of students' practice and innovation ability should be strengthened.

As a consequence, the objective of the Outstanding Engineer's Talent Programme is the training of high-quality engineering and technical graduates to engage in the design and manufacture of metallurgical machinery, science and technology development, application research, operation management, operation and sales, operation and maintenance, and engineering management [5].

IMPLEMENTATION OF INDIVIDUALISED TEACHING MODE

Reform Programme of Dual Tutorial System

During the College learning period, the dual tutorial system of *academic tutor + quality tutor* is implemented and the dual tutorial system of *academic tutor + enterprise tutor* is implemented in the training project of university-enterprise cooperation. The academic tutor role is held by professional teachers with at least a sub-senior professional title. They should be experimental engineers or good teachers who have worked for more than four semesters, who should carry out two-way interaction with students at the end of each semester and are responsible for guiding students' learning.

The quality supervisors are arranged by the College; they are responsible for guiding students' thoughts and their daily lives. The enterprise tutors are line of engineering and technical people who are arranged by enterprises and equipped with a senior technical title, rich engineering practical experience related to the major and more than five years working time in the enterprise. They are responsible for guiding students' internship in enterprises. The dual tutorial system is shown in Table 3.

Table 3: Dual tutorial system.

Training form	Type of tutor	Main duty of tutor
Cultivation in College	*academic tutor + quality tutor*	Guidance of students' learning and daily life
Cultivation of university-enterprise cooperation	*academic tutor + enterprise tutor*	Guidance of students' learning and internship

Outstanding engineering training is focused on the practical ability of students, and enterprise tutors have a unique advantage in this area. Therefore, the students will experience a substantial improvement in their practical abilities under the guidance of the enterprise tutor. A dual tutorial system has been implemented for undergraduate students, beginning from the first semester of undergraduate teaching each year until the completion of all studies. The leading group of the College is established by the dean, secretary, director of the Department of Teaching and Research, director of the experimental centre and counsellors, who are responsible for implementation and management of the tutorial system.

The implementation process of the dual tutorial system should be as follows:

1. Management of the tutorial system is established for the selection between students and tutors and the management of day-to-day affairs;
2. A two-way selection mechanism between academic tutors and students is established; first, through the management system of tutorial system, the personal information, research and practice (experiment) capacity requirements of academic tutor and enterprise tutor are published for students, then, the guiding ideology, implementation scheme and operation procedure are introduced, so that students can make informed choices of their tutors;
3. Students are equipped with an academic mentor from the first semester and an enterprise tutor from the fifth semester;
4. Students choose an academic mentor and enterprise tutor according to their personal interests and each person has only three volunteers;
5. According to the order of students' volunteers, the two-way choice is carried out between students and the teacher or enterprise technical personnel. The college then makes the final adjustment to determinate which students will be guided by each academic mentor and enterprise tutor, and the maximum number of students to be guided by each academic tutor and each enterprise tutor.

Implementation of Small Class Teaching

The mode of small class teaching is as follows: small class teaching is adopted for all pilot classes; professional courses are gradually implemented into small class teaching, in which fewer than 40 persons account for more than 40% of the total annual commencement. The teaching method of large class teaching combined with small class tutorship is adopted for *mechanical principles*, *hydraulic transmission* and *mechanical drawing*, and other core sections of the curriculum. The teaching method of large class teaching combined with small class tutoring of the professional basic course is established by the College of Machinery and Automation within three semesters.

Depending on the number of students in the selected course, the number of students can be divided into groups of no more than 40 for small class teaching, for teaching of the theoretical part by one or more teachers. Teachers should provide curriculum-related answers and homework help after class. The courses, which involve practical work arranged by the experiment teacher are taught in experimental groups of three or four students. Professional orientation courses are also carried out in small class teaching, such as smelting production technology and equipment, rolling production technology and equipment, electro-hydraulic system design, device troubleshooting, advanced signal process, advanced stress analysis and other specialty courses. The small classes of fewer than 40 persons are used for teaching methods of projects traction, heuristic, inquiry, discussion and participation [6]. After four semesters of reform, professional courses using small class teaching accounted for more than 40% of annual courses.

Individualised Teaching Methods

Based on the double tutorial system, the academic tutor should guide students' professional learning orientation, cultivate learning interests, help students to develop purposeful and targeted individual learning plans, cultivate students' comprehensive application ability for expertise, and guide students' scientific research, academic thesis, graduation thesis, phase of internship, graduation practice, employment, etc. Simultaneously, enterprise tutors are

responsible for the students' learning in the enterprise or during the internship, and they must guide students' attendant training, graduation practice and graduation design and other practical aspects with the College academic tutors.

DEEPEN PRACTICAL TEACHING PLATFORM CONSTRUCTION

In order to promote practice teaching better, the practice teaching platform should be reformed. The construction of teaching platform is shown in Figure 1.

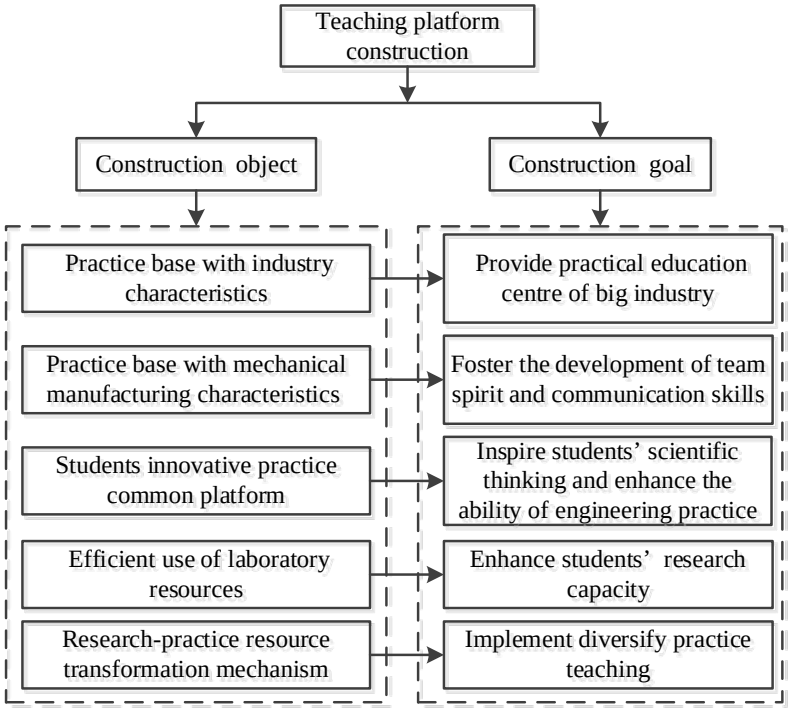

Figure 1: Construction of the teaching platform.

Construction of the Practice Base with Industry Characteristics

Wuhan University of Science and Technology - Wuhan Iron and Steel (Group) Company National Engineering Practice Education Centre has been established to provide practical education for students' practical training [7]. This Centre is based on the College's strengths in metallurgy, the advanced production technology, outstanding practice environment and scientific researchers of the Wuhan Iron and Steel (Group) Company (WISC), aided by the resources of the National Silicon Engineering Technology Research Centre, the Hubei Automotive Steel Engineering Technology Research Centre, the Wuhan Iron and Steel Museum and other sources.

Construction of the Practice Base with Mechanical Manufacturing Characteristics

Referring to the construction standard of the National Engineering Practice Education Centre of Wuhan University of Science and Technology - Wuhan Iron and Steel (Group) Company and the Practice Base of Wuhan University of Science and Technology - Wuhan Marine Machinery Company, the construction of university-enterprise joint practice bases should be strengthened. Through the construction of a university-enterprise joint practice training base, students can learn metallurgical production processes, the structure and working principle of metallurgical machinery, design specifications, industry standards of metallurgical machinery and specialised technical knowledge of production, manufacture, installation and maintenance. It is an effective way for students to understand the current situation and development of mechanical engineering and cultivate the spirit of teamwork and communication skills [8].

Construction of a Public Platform for College Undergraduates' Innovation Practice

The National College Student Mechanical Innovation Design Competition *Challenge Cup* and other extracurricular academic science and technology competitions can be used as a carrier to expand the undergraduates' science and technology innovation base and build the undergraduates' innovative practice public platform. The students' research and creative ability can be strengthened by these methods.

Undergraduates' science and technology innovation laboratory can be built by investing in special funds, which consists of three subject laboratories: robot creative laboratory, mechanical and electrical innovative design laboratory and engineering ability training laboratory. The robot creative laboratory is used to realise the cognition of mechanical science and the enlightenment of scientific thinking. The electrical and mechanical innovation design laboratory is used

to help students to carry out mechanical and electrical systems or product innovative design, which aims to help the students in active thinking, and creative and innovative exercises. The purpose of the engineering ability training laboratory is to realise the transformation from theory to practice and cultivate the comprehensive talents with good skills and practices.

Full Use of the Laboratory Resources

Students participate in the research and engineering practice of the Key Laboratory of the Ministry of Education on Metallurgical Equipment and Control. New projects are mainly combined with actual scientific research projects, which are usually offered to more outstanding students. The cultivation of outstanding engineers, which is combined with the study on the structure and mechanical behaviour of metallurgical equipment, is based on laboratory resources, which include a controlled mechanism experimental table, a strip surface quality testing system, a metallurgical process control system and other advanced systems. Based on these systems, the cultivation of students' scientific research ability could be achieved.

Establishment of Mechanism on Transformation of Scientific Research into Practical Resources

A mechanism to assist the rapid transformation of scientific research resources to educational resources should be established. The design of applied, design-based, integrated and innovative experimental projects about the steel and automobile equipment manufacturing industry specialty orientation course should be based on research projects and enterprise joint research projects. Universities should establish an *Undergraduate Research Project* programme to encourage outstanding undergraduates to become involved with the academic tutors' research projects. The College also can set up a Scientific Research-Teaching Resources Transformation Fund, which would mainly be used for the acquisition and transformation of teaching resources, etc, and which should be necessary for the completion of the newly developed experimental projects. All of these will help achieve the final realisation of diversified practical teaching with professional features.

JOINT TRAINING MODE AND PRACTICAL EFFECT

Relying on the *Innovation Ability of Institutions of Higher Learning Promotion Plan* (*2011 Plan*) - a synergy between the steel industry and innovation centre has been established. A metallurgy collaborative innovation base has been set up between iron and steel, and the joint training mode has been established [9]. The joint training mode and its practical effect is shown in Figure 2.

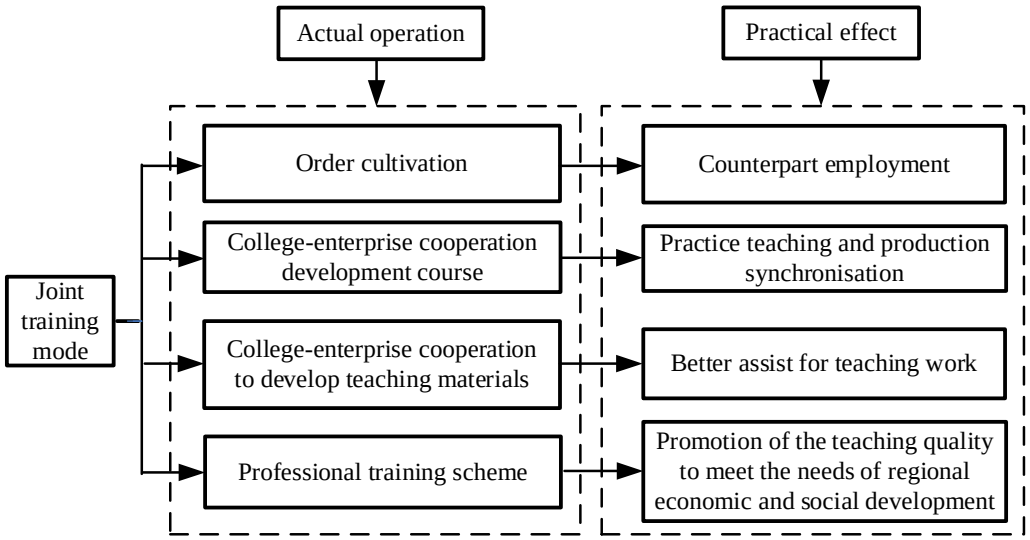

Figure 2: Joint training mode and the practical effect.

Order Training Mode

Based on the comprehensive strength of the profession, the needs of the local area and the region's larger enterprises should be understood. Also, active communication with WISC, DongFeng Motor and other companies to make students learn the knowledge and skills, which are much needed. 30~50 people will be trained for WISC and Dong Feng Motor. Each part should clearly know the responsibilities. Recruiting students should be charged by the College. According to the demands of each enterprise, a teaching plan, which is suitable for achieving the training goal should be established, as should an appropriate implementation of teaching with the enterprise to guide the students' orientation training. A corresponding professional qualification certificate can be obtained after graduation and the students can also be employed in the local area or beyond. Through this kind of order training mode, the practical effects can be made to let the students get a job, which matches their profession.

Curricula Developed through Cooperation between University and Enterprises

Teaching plans and training standards are drafted by both parties. Student's basic theory and professional theory is the responsibility of the College, and the production practice and field works are furnished by the enterprise. When the curriculum implementation process is completed, the work-integrated learning and field work is the first choice. The characteristics of the developed curriculum should be as follows:

1) modularisation of curriculum structure;
2) integration of curriculum content;
3) integration of curriculum implementation;
4) evaluation of opening curricula.

The effect of college-business cooperation development courses is the realisation of synchronisation of teaching and production, practice and employment.

Textbooks Developed through Cooperation between University and Enterprises

Textbook development should be based on the implementation of curriculum development. Experts and teachers prepare teaching materials that should be aimed at the characteristics of professional courses and combined with the working environment of students in the relevant enterprises. Materials can start from the lecture notes and, then, according to the actual use of the situation should be gradually revised in the final transition to college-based teaching materials and the formal publication of textbooks. Cooperation between colleges and enterprises facilitates development of teaching materials and makes the teaching work better, and improves curriculum and real-time teaching.

Professional Training Programmes

In setting up a training plan, the advanced development requirements should be fully investigated and predicted. In the preliminary stages, professionals and experts should be identified and invited to demonstrate various approaches, which can enhance the training programme of scientific and practical application. Employment should be the guideline to meeting the needs of regional economy and social development.

CONCLUSIONS

The cultivation of outstanding engineers at Wuhan University of Science and Technology has been achieved via a diversified personnel training mode. This has led to the cultivation of all-round development and high-quality engineering and technical talent in machinery design and manufacturing, as well as technology development, application research, operation management, sales, maintenance and engineering management.

The authors have established a variety of training models, fully accepting a point credit system and a dual tutorial system and small class teaching. These have achieved dynamic assessment mechanisms, and they have strengthened the construction of the university-enterprise practice training base and construction of college students' innovative public practice platform to achieve the construction of talent in the university-enterprise training base and, thus, embarked on the road of international personnel training. At the same time, the exploration of cultivation of outstanding mechanical engineers is a long process and needs to be developed steadily. Only in this way can the system cultivate more outstanding mechanical engineers.

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REFERENCES

1. Jiang, G., Li, X., Li, G., Qin, M. and Zhou, Y., Reform of the examination and evaluation system for the mechanical specialty in universities. *World Trans. on Engng. and Technol. Educ.*, 13, **4**, 620-626 (2015).
2. Zhang, R., Hu, T., Ma, K., Zhao, H., Wang, W. and Mao, W., An IT talent cultivation mode driven by actual projects - based on research using questionnaires and interviews. *World Trans. on Engng. and Technol. Educ.*, 12, **1**, 65-72 (2014).
3. Zhou, Y., Wang, B. and Ju, C., The cultivating of information literacy and information technology in a classification talent training system. *World Trans. on Engng. and Technol. Educ.*, 12, **1**, 43-48 (2014).
4. Li, G., Liu, J., Jiang, G., Kong, J., Xiong, H., Sun, Y. and Liu, H., Application of modern simulation technology to a theory of mechanics course intended for outstanding engineers. *World Trans. on Engng. and Technol. Educ.*, 12, **1**, 54-59 (2014).
5. Sun, Y., Jiang, G., Li, G., Xiong, H. and Tao, P., Application of modern simulation technology in a mechanical design course for outstanding engineers. *World Trans. on Engng. and Technol. Educ.*, 12, **2**, 203-208 (2014).

6. Yang, G., Combining competitions with classroom teaching to cultivate students' engineering capabilities. *World Trans. on Engng. and Technol. Educ.*, 12, **1**, 127-131 (2014).
7. Gu, Q., Wang X., Wu, Z. and Hua, L., Exploration and practice of college-enterprise co-operation talent cultivating in computer science at local universities. *World Trans. on Engng. and Technol. Educ.*, 12, **1**, 20-25 (2014).
8. Zhou, Y., Gao, L. and Zhou, J., Building practical talents training mode through college-enterprise co-operation in a mechanical major. *World Trans. on Engng. and Technol. Educ.*, 12, **1**, 84-88 (2014).
9. Wang, S., Cai Y. and Wang X., A model to strengthen mechanical engineering training. *World Trans. on Engng. and Technol. Educ.*, 12, **1**, 105-110 (2014).