Competency-based Framework for Cultivating Innovation Capabilities of Mechanical Graduate Students: One Core, Two Centers, and Five Capabilities

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ABSTRACT

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| Under the background of the strategy of ‘Manufacturing Power’ in the new era, the proportion of professional degree postgraduates is increasing, but some problems are reflected in the process of their cultivation. Taking the mechanical professional degree postgraduates as an example, the professional degree postgraduates are facing the challenges of insufficient practical innovation ability and imperfect university-enterprise collaborative cultivation mechanism. In view of the above problems, this paper proposes the innovative cultivation mode of ‘one core, two centres, five cultivation capabilities’, i.e., the core of moral education, the ‘two centres’ drive of collaborative cultivation of university and enterprise tutors, and the ‘five cultivation capabilities’ drive around the application of knowledge, communication and expression, project summarisation, and innovation development, The model is driven by ‘two centres’ through the collaborative training of university and enterprise tutors, and ‘five cultivation capabilities’ of knowledge application, communication expression, project summarisation, innovation development and cycle control, and formed the whole chain training path of ‘value leadership - ability progression - evaluation and closure’ with the guarantee of parallel evaluation system of university and enterprise. The aim is to solve the current problems in the cultivation of master's degree students in mechanical engineering and to improve the engineering practice and innovation ability of students. |

*Keywords: Mechanical degree postgraduates; Practical innovation ability; One Core, Two Centres; Five Cultivation Capabilities; University-enterprise collaboration*

1. INTRODUCTION

**1.1Background and significance of the study**

With the intensification of global scientific and technological competition and the acceleration of industrial upgrading, China has put forward the strategy of ‘manufacturing power’, which aims to promote the high-quality development of manufacturing industry. Under the background of new engineering, the significant expansion of the scale of specialised master's degree has brought unprecedented challenges to the cultivation of specialised master's degree. The quality of the training of specialised master's degree students has a great impact on the development of the national manufacturing industry. Machinery is the foundation of the manufacturing industry, providing a solid backing for the country's economic growth and social progress. However, there are problems such as insufficient practical innovation ability and imperfect university-enterprise collaborative cultivation mechanism in the cultivation process of current mechanical professional degree master's degree students, and a new cultivation mode is needed to solve these problems.

**1.2Overview of the current status of domestic and overseas research**

**1.2.1Current status of foreign research**

In terms of talent training, foreign developed countries started early and constructed a perfect theoretical system. Germany through the professional certification organisation system, the development of students' training is closely integrated with the engineering reality; the United States emphasizes the integration of industry and education, and cultivates technical talents oriented to the needs of enterprises. Based on the diversified cultivation mode, strict evaluation system and rich practice opportunities, the postgraduates cultivated in these countries have good practical innovation ability and employment competitiveness.

**1.2.2Current status of domestic research**

In recent years, the proportion and number of professional degree postgraduates enrolled in China's universities and research institutes have been increasing, but the quality of cultivation still needs to be improved. Taking East China Jiaotong University as an example, Li Gang and others analysed the existing problems of innovation ability cultivation of mechanical postgraduates, proposed that their innovation ability should be improved with the help of scientific research project practice, and gave a series of initiatives [1]. Zhong Wei analysed the requirements of new engineering science on the ability of scientific and technological talents, pointed out the current deficiencies in the innovation training of postgraduates, and proposed to improve their innovation ability by the reform of diversified scientific research practice [2]. Combined with the standards set by the Ministry of Education, Chen Xifu et al. summarised the characteristics that should be possessed by China's professional masters of engineering, and put forward the optimization way of China's professional degree graduate training by studying the German graduate training method and its role in engineering quality [3]. Domestic scholars have studied the cultivation mode of mechanical professional degree masters, pointing out that there are problems such as irrational curriculum, lack of practical teaching links and incomplete university-enterprise collaboration mechanism [4-6]. In view of these problems, reform measures such as strengthening practical teaching, improving university-enterprise cooperation mechanism and optimising the curriculum system have been proposed. However, the research on the existing problems focuses on the improvement of a single aspect, while the overall innovation of the training mode is lacking.

**1.3 Purpose of the study**

The purpose of this paper is to solve the problems of insufficient practical innovation ability in the cultivation process of the current mechanical professional degree master's degree students through the exploration of the innovative cultivation mode of ‘One Core, Two Centres, Five Cultivation Capabilities’, and to continuously improve the engineering practice and innovation ability of the students.

2. Theoretical basis and connotation of the construction of the ‘One Core, Two Centres, Five Cultivation Capabilities’ model

**2.1 Rationale**

**2.1.1 Constructivist learning theory**

Constructivist learning is a theory of learning that emphasises the active construction of learners' understanding and meaning of knowledge. In the process of interaction with the environment, learners actively construct their own knowledge system rather than passively accept it. In the model of ‘One Core, Two Centres, Five Cultivation Capabilities’, through project practice, research and innovation activities, students are allowed to actively construct the knowledge framework in real situations, and to combine theoretical knowledge with practice to improve their innovation and practice ability [7,8]. For example, in the enterprise internship project, students need to face the actual engineering problems, in order to better solve the problem, they need to take the initiative to look for ways to solve the problem by consulting the information, discussing with team members, consulting the tutor and so on, through which a series of methods can enable students to better integrate the theoretical knowledge with the engineering practice, so as to deepen the understanding and application of professional knowledge.

**2.1.2 Collaborative Parenting Theory**

The theory of collaborative cultivation emphasises the collaborative and cooperative relationship between educational subjects. In the ‘One Core, Two Centres, Five Cultivation Capabilities’ model, enterprises and schools act as the main educational bodies, and students are jointly cultivated by tutors in enterprises and tutors in schools, so as to achieve the purpose of sharing resources and complementing each other's strengths. School tutors have solid academic knowledge and teaching experience, and can provide students with systematic theoretical guidance [9,10]. At the same time, the enterprise mentors have rich engineering practice experience and industry resources due to their long-term contact with engineering projects, and they can provide students with practical guidance and career planning advice. Both sides participate in the cultivation process of postgraduate students through regular communication, joint guidance and on-site teaching, which can improve students' comprehensive quality and innovation ability.

**2.1.3 Competency-based education theory**

Competency training is the core of competency-based education theory. In the "One Core, Two Centres, Five Cultivation Capabilities training" model, students should be trained closely around the Five Cultivation Capabilities of knowledge application, communication expression, project summary, innovation and development, and cycle control. The cultivation of these Five Cultivation Capabilities can ensure that students can adapt well to the development of society. At the same time, these Five Cultivation Capabilities are also the core abilities that mechanical professional master's degree students must possess in their careers. Targeted training of these Five Cultivation Capabilities can enable students to better adapt to the needs of enterprises and improve their employment competitiveness when facing employment problems in the future.

**2.2 Model Connotation**

**2.2.1 One Core: Moral education**

The fundamental task of education is to cultivate morality and cultivate people. In the process of education, we should focus on cultivating students' moral qualities and make them truly useful to society. In the "One Core, Two Centres, Five Cultivation Capabilities training" model, by strengthening students' establishment of a correct world outlook, outlook on life and values, their sense of social responsibility, innovative spirit and ability are improved. In this model, ideological and political education for students runs through the entire training process. The school cultivates students' patriotism, professional ethics and social responsibility through ideological and political courses, theme class meetings and social practice activities; organizes students to visit red education bases to let students have a deep understanding of the party's development history and revolutionary process, so as to inspire students' patriotic enthusiasm and mission; at the same time, it can also invite outstanding employees of enterprises to give regular professional ethics lectures, so that students can better understand corporate culture and values ​​through the learning process.

**2.2.2 Dual Hearts: School-Enterprise Dual Mentors Collaborate to Educate People**

School mentors are mainly responsible for the construction of students' theoretical knowledge, while enterprise mentors can guide students to combine theoretical knowledge with engineering applications through specific engineering practices. School mentors and enterprise mentors can achieve an organic combination of students' theory and practical application through joint guidance. School mentors formulate personalized training programs for students based on the frontier development of the discipline and students' interests, and guide students in the selection of research topics, research of theoretical knowledge and writing of papers. Enterprise mentors can help students to make further development plans and cultivate their abilities according to the needs of enterprises and the development of the market, so that students can have better solutions when facing engineering practice problems. For example, for a certain practical project of an enterprise, school mentors and enterprise mentors can jointly guide students to participate in this project, so that students can apply the knowledge they have learned in practice to improve their comprehensive ability to solve complex problems.

**2.2.3 Five Cultivation Capabilities: progressive ability cultivation**

In the process of student training, a progressive training system is constructed around the Five Cultivation Capabilities of knowledge application, communication expression, project summary, innovation and development, and cycle control. Students have different needs at different stages, and students are trained to develop their abilities according to this problem. In the course learning stage, the cultivation of students' knowledge application ability should be the focus, and students can apply the knowledge they have learned to practical problems through case analysis, course design, and field visits. In the practical stage of the project, we should focus on cultivating students' communication, project summary and innovative development capabilities, which can be achieved through group discussions, project reports, project summaries, etc. The above methods can improve students' teamwork and problem-solving abilities. In the stage of graduation design, we should focus on cultivating students' ability to control the cycle, so that students can learn to make project plans, break down goals, reasonably grasp progress and summarize experience in a timely manner to improve project management capabilities.

3. The practical path of the "One Core, Two Centres, Five Cultivation Capabilities training" model

**3.1 Value guidance: Moral education runs through the entire training process**

**3.1.1 Ideological and political education is integrated into the curriculum system**

Teachers should integrate ideological and political education into the study of professional courses, and guide students to establish correct values and professional views through case analysis, special lectures, etc. For example, in the mechanical design course, some typical engineering ethics cases are analyzed to guide students to establish correct professional ethics concepts;

**3.1.2 Professional ethics education runs through the practical links**

Students should strengthen their professional ethics education and focus on cultivating students' professional ethics and moral qualities during their internships, scientific research projects and other practical links. This task is mainly undertaken by corporate mentors. In the process of guiding students, corporate mentors should strengthen the cultivation of students' professional ethics awareness, such as abiding by corporate rules and regulations, keeping corporate secrets, and respecting others' intellectual property rights. Corporate mentors can lead students to actively participate in professional ethics training, case analysis and other activities. Through these activities, students can understand the importance of professional ethics and improve their professional ethics.

**3.1.3 Cultivation of social responsibility awareness**

Students can cultivate social responsibility awareness and enhance their sense of responsibility by actively participating in social practice, volunteer service and other activities. Schools and enterprises can organize students to participate in community service, environmental protection activities, patriotism propaganda and other social practice activities to let students understand social development and needs. The purpose of scientific research is to serve the society. Through this process, students' sense of social responsibility can be enhanced. At the same time, it can also inspire students to explore the direction of scientific research, so that students can understand social needs and contribute to the development of society.

**3.2 Ability advancement: building a progressive training system**

**3.2.1 Strengthen basic knowledge and skills learning**

Currently, many courses offered for student training are out of touch with the times, and many courses are offered only to give students credits, which makes it difficult for students to use the knowledge they learn in class in reality. By optimizing the course system, streamlining the course schedule, and strengthening the teaching of professional basic courses and practical courses, students can be ensured to master solid professional knowledge and skills. At the same time, during the course explanation, teachers should introduce cutting-edge industry technologies and cases to broaden students' horizons and ideas.

**3.2.2 Improving practical innovation capabilities**

The improvement of innovation ability is not achieved overnight. The tutor can organize students to participate in innovation and entrepreneurship projects to stimulate students' innovative thinking and creativity. In their spare time, tutors should encourage students to actively participate in scientific research projects, corporate internships, innovation and entrepreneurship competitions and other activities, so that students can continue to grow in practice and further exercise their ability to find and solve problems. The school can provide students with a scientific research platform, and the relevant national policies can also provide students with financial and material support. The internship base established by the school and the enterprise can provide students with good internship opportunities. Students can participate in scientific research projects jointly carried out by the school and the enterprise, and cooperate with the enterprise to carry out technology research and development, and transform scientific research results into actual products.

**3.2.3 Cultivate communication and expression and teamwork skills**

Cultivating students' communication and expression skills and teamwork skills can be achieved through group discussions, project reports, teamwork and other methods. Students have the ability to clearly express their own opinions and ideas, which can enable them to better collaborate effectively with team members. In the course teaching, the traditional classroom format of teachers lecturing and students listening should not be adopted, but group discussion and group reporting should be adopted. Students should discuss and communicate on a certain issue, and the teacher should comment after listening to the students' reports, so as to improve students' communication and expression skills. In the process of project practice, students are required to report on the project, and this way can be used to exercise students' communication and expression skills. At the same time, actively organizing students to participate in team projects can also cultivate students' teamwork spirit and leadership ability.

**3.2.4 Exercise project summary and cycle control ability**

In the process of participating in actual projects, students should be trained to learn how to make project plans, break down tasks, control progress and summarize experience. Students should learn project management knowledge and improve project management capabilities. At the same time, they should summarize and reflect regularly, absorb project experience, and form complete project reports and papers. In the process of enterprise internship, students should actively participate in enterprise projects and exercise project summary and cycle control capabilities through practice. In the early stage of entering the enterprise, the school can offer relevant project management courses, systematically impart project management knowledge and methods, so that students can better adapt when entering the enterprise.

**3.3 Evaluation closed loop: Establish a parallel evaluation system between school and enterprise**

**3.3.1 Clear evaluation standards**

Clear evaluation standards should be formulated for the training of students, including academic performance, scientific research ability, practical performance, engineering application ability, etc., and the fairness and objectivity of the evaluation should be ensured during the evaluation process. The evaluation of academic performance is mainly based on the students' course test scores and the quality of the papers; the evaluation of scientific research ability is mainly based on the number and quality of the scientific research projects participated by the students, the publication of academic papers, etc.; the evaluation of practical performance is mainly based on the students' performance in the enterprise internship, the quality of the completed project tasks, etc.; the evaluation of engineering application ability is mainly based on the students' ability to solve practical engineering problems and the degree of mastery of industry technology, etc.

**3.3.2 Regular assessment feedback**

Schools and enterprises can conduct regular assessments on students so that students can understand their strengths and weaknesses from the assessment results. Students can adjust their future efforts based on the assessment results. Course exams, project defenses, and practice reports can all be used as assessment methods. After the assessment, school mentors and enterprise mentors can communicate the assessment results to students in a timely manner through interviews, written reports, etc. To ensure the comprehensiveness and accuracy of the evaluation, this requires school mentors and enterprise mentors to participate in this process together.

**3.3.3 Strengthen communication and collaboration**

The training and development of students is completed under the joint guidance of school mentors and enterprise mentors. The two mentors should actively communicate in terms of student training, hold regular joint meetings of dual mentors to discuss and exchange students' training status, and have a deep understanding of the problems encountered by students in the training process. For problems that students may encounter, such as unsuccessful project progress and students' learning difficulties, school mentors and enterprise mentors should jointly help students analyze the causes of the problems and guide students to solve them. At the same time, in order to fully cultivate students' academic and practical abilities, school mentors and enterprise mentors should also jointly formulate training plans and assessment standards for students.

1. Challenges and countermeasures of the "One Core, Two Centres, Five Cultivation Capabilities training" model

**4.1 Challenges faced**

**4.1.1 School-enterprise collaboration is difficult**

The reason why the collaboration between schools and enterprises is difficult is that there are cultural differences and different interests between the two. From the perspective of schools, they focus on academic research and talent training. However, the fundamental purpose of the development of enterprises is to obtain higher economic benefits. In the process of cooperation, the two parties may have certain differences due to inconsistent goals. For example, the school's goal is to enable students to improve their scientific research capabilities through participating in the company's scientific research projects; while the company may pay more attention to the economic benefits of the project and is unwilling to invest too much resources in the training of students.

**4.1.2 The effectiveness of dual-tutor guidance varies**

The professional background and work experience of school tutors and enterprise tutors are not exactly the same, which leads to uneven guidance effects of dual tutors. Some school tutors have a deeper understanding of textbook theoretical knowledge, but they may participate in fewer engineering practice projects, which will lead to their lack of engineering practice experience, resulting in insufficient in-depth practical guidance for students; some enterprise tutors are busy with work and may not be able to provide timely guidance to students. In addition, if there is a lack of communication or different opinions between the dual tutors, there may be deviations in the guidance content for students, which further confuses students about the direction of their future efforts.

**4.1.3 The evaluation system needs to be further improved**

The existing evaluation system for students is still insufficient and needs to be further improved. From the two aspects of the evaluation content and evaluation method of students. The publication of academic papers and course grades have become the main considerations in the evaluation of students. However, over-emphasizing the publication of academic papers and course grades will neglect the evaluation of students' practical ability and innovation ability, and further guide students to not pay attention to the cultivation of their own practical innovation ability; in terms of the evaluation method of students, the evaluation of teachers is mainly based on the evaluation of teachers, which will lead to certain limitations. In the evaluation process, students' self-evaluation, mutual evaluation between students and enterprise evaluation should be included to evaluate students from multiple aspects. In addition, the evaluation results should be fed back to students in a timely manner to further guide their development.

**4.2 Countermeasures and Suggestions**

**4.2.1 Strengthen communication and cooperation between schools and enterprises**

School mentors and enterprise mentors should establish a regular communication mechanism to strengthen information communication, exchange and cooperation between schools and enterprises. Schools and enterprises can set up a school-enterprise cooperation committee to discuss the progress of cooperation projects, existing problems and solutions through regular meetings. School mentors and enterprise mentors should jointly participate in the formulation of student training plans and the setting of assessment standards. Schools and enterprises should each play to their own strengths to comprehensively train students. The school trains students in theory and sends students who have mastered theoretical knowledge to enterprises. Enterprises let students combine theory with practice through actual engineering projects, so as to better serve the society.

**4.2.2 Improve the guidance ability of dual mentors**

The personal abilities of enterprise mentors and school mentors and their communication and collaboration abilities will directly affect the training effect of students. Therefore, both schools and enterprises should strengthen the training and assessment of dual mentors. Specifically, relevant measures can be formulated to improve the guidance level and collaboration ability of school mentors and enterprise mentors. As for schools, they should organize school mentors to conduct engineering practice training in enterprises on a regular basis. During the training process, not only can the school mentors enhance their understanding of the needs of enterprises, but also promote the updating and expansion of their professional knowledge. Enterprises can also regularly organize corporate mentors to come to schools to provide teaching guidance to students, which can not only strengthen the communication between corporate mentors and students, but also improve their teaching ability and guidance level. At the same time, both the school and the enterprise should also establish a dual-tutor incentive mechanism, and provide certain material rewards and honorary recognition for dual tutors who have excellent performance in guiding students, and at the same time, corresponding policy support should be given in terms of professional title promotion.

**4.2.3 Improve the evaluation system**

The school and the enterprise should jointly establish a scientific, reasonable and comprehensive evaluation system, which mainly includes the following aspects: academic performance, scientific research ability, practical performance, and engineering application ability. At the same time, a variety of evaluation methods should be adopted, such as student self-evaluation, student mutual evaluation, tutor evaluation, and enterprise evaluation to ensure the fairness and objectivity of the evaluation. After receiving the evaluation information, the school and the enterprise will promptly feedback the evaluation results to the students, so that the students can understand their strengths and weaknesses and adjust their learning strategies and directions according to the feedback results. Finally, the evaluation results are linked to the students' scholarship evaluation, outstanding graduate selection and other honors to give full play to the incentive and guidance role of the evaluation.

5. Conclusion

This paper proposes an innovative training model of "One Core, Two Centres, Five Cultivation Capabilities" for mechanical professional degree master students. Through measures such as moral education, school-enterprise dual mentors, progressive ability training and school-enterprise parallel evaluation system, it provides a solution for improving the practical innovation ability of mechanical professional degree master students. This model has the advantages of systematicity, synergy, progressiveness and closed loop, and provides a useful reference for the reform of professional degree graduate education.

Consent (where ever applicable)

All authors declare that ‘written informed consent was obtained from the patient (or other approved parties) for publication of this case report and accompanying images. A copy of the written consent is available for review by the Editorial office/Chief Editor/Editorial Board members of this journal.

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Option 1:

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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