

Exploration and Practice on Cultivating Graduate Students' Scientific Research and Innovation Ability in Mechanical Engineering

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Abstract: On the background of China becoming a global manufacturing powerhouse, targeted measures are provided to enhance the scientific research and innovation capabilities for mechanical engineering graduate students. It is critical to prioritize fostering students' abilities to independently tackle complex engineering problems and drive technological innovation in graduate education. Three foundational supports are identified, which are solid basic skills in mathematical modeling and precision measurement, advanced research conditions including state-of-the-art labs and stable funding, and systematic training via participation in major national projects and industry internships. Four core factors are emphasized, which are interdisciplinary teaching reform integrating cutting-edge technologies, high-level research platforms for collaborative innovation, mentor teams combining academic expertise and industrial experience, and dynamic feedback mechanisms for continuous improvement. Practice proves this model effectively fulfills the fundamental task of cultivating students with moral integrity, significantly enhances innovation capabilities, improves professional degree graduate training quality, and delivers remarkable outcomes worthy of widespread promotion in similar fields across the country.

Keywords: Scientific Research Innovation Capability; Cultivation Mode; Supporting Conditions; Core Factors

1. Introduction

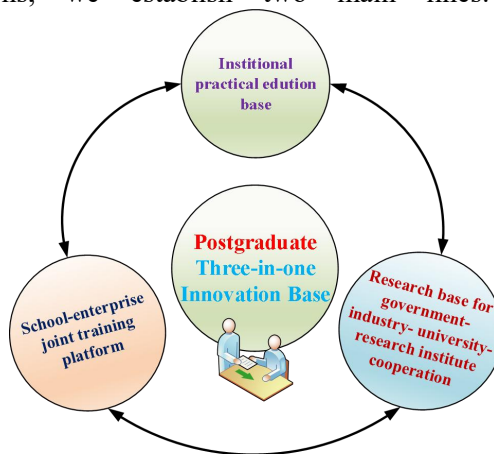
The cultivation of graduate students should not only focus on the learning and accumulation of knowledge, but also on enhancing their ability to conduct scientific research and innovate. In the new era, the demand for technological innovation talents in the country is increasing. Many aspects, such as the education-oriented

mechanism and training links, need to be continuously improved and perfected. Cultivating innovative talents has become the main theme of the times. Developed countries prioritize the cultivation of graduate students' innovation capabilities, actively encouraging them to embrace scientific research, stimulate new thinking and creativity. They promote innovative education for graduate students through "government-university-industry-research collaboration", and establish a joint training model for enterprise technology development and academic talent [1,2]. Scholars such as Li Binghong have proposed that "big platform" practice bases can effectively solve the common problem of engineering graduate education practice bases, facilitating school-enterprise cooperation and realizing the integration of industry and education [3-5]. Scholars such as Tian Rujin believe that multi-dimensional and comprehensive collaborative training can effectively enhance the innovation ability of graduate students, and is an important measure to promote the sustainable development of the national innovation system [6,7]. Gu Jinan and Wang Lei have explored new models for cultivating the innovation ability of mechanical engineering graduate students, proposing new interdisciplinary training programs for their innovation ability, as well as project-driven training programs for their innovation ability [8,9]. By collaborating with enterprises, jointly building experimental innovation platforms, breaking down disciplinary boundaries to create a shared public experimental platform, continuously expanding graduate student research and practice activity bases, and complementing with continuous improvements in evaluation mechanisms, process control, and implementation routes, we explore mechanisms and routes for comprehensively cultivating the innovation ability of mechanical engineering graduate students. We aim to construct a complete new model suitable for the cultivation

of research and innovation ability of mechanical engineering graduate students in our university and similar universities, and provide reference for the cultivation of graduate students in other related majors.

2. A New Model for Cultivating Postgraduate Students' Scientific Research and Innovation Abilities

Combining the characteristics of four research directions in our school's mechanical engineering discipline, namely advanced manufacturing technology, electromechanical system control technology, additive manufacturing technology, and new energy equipment technology, we explore and practice new models for enhancing the scientific research and innovation capabilities of graduate students. Based on the professional training plan, teaching and research platform, and cutting-edge research directions, we establish two main lines:



exploring the connotation and influencing factors of graduate students' scientific research and innovation capabilities, and constructing models to enhance these capabilities. We provide "three major supports", achieve "four in one", and improve "five measures", thereby enhancing the scientific research and innovation capabilities of our graduate students and promoting the comprehensive ability cultivation of our graduate students to a new historical height.

3. Establish Three Major Supporting Conditions

In order to better serve the development of the national economy and lead the innovation ability education of graduate students to a new level, three major supports are provided, as shown in Figure 1, to ensure that the reform subjects are targeted and the reform goals are practical and feasible.

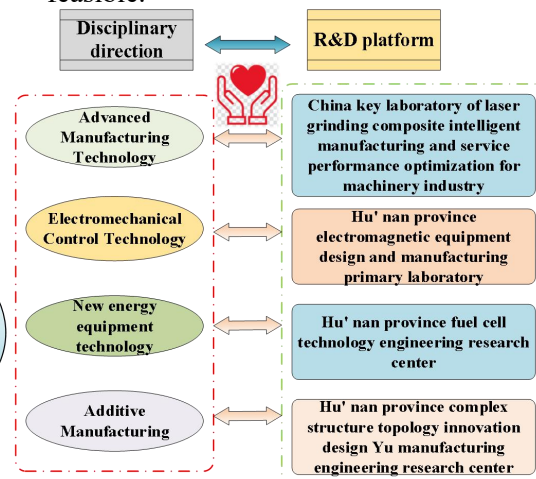


Figure 1. Three Major Supports

3.1 Basic Skills are the Foundation

Adopt classroom education under the guidance of mentors. At this stage, focus on cultivating graduate students' professional basic knowledge, fundamental theories, and comprehensive qualities. Emphasize the provision of foundational courses such as aesthetics, philosophy, management cost, engineering technology, professional ethics and qualities, to enhance professional knowledge, grasp fundamental theories, and strengthen comprehensive qualities.

3.2 Guarantee with the Construction of Scientific Research Conditions

Integrate research resources both inside and outside the university, and collaborate with

project partner enterprises to build an open innovation experiment platform, providing a hardware foundation for enhancing the innovation capabilities of graduate students. Combine the dual-mentor model of university mentors and enterprise mentors to guide graduate students from theoretical research towards practical development in enterprises, pursuing cutting-edge technologies and key breakthroughs in sub-fields urgently needed by society, thereby achieving technological development capabilities. Align with national requirements for scientific research development, and with organized scientific research teams as the guide, build innovative teams with clear division of labor and cooperation, enhancing the conditions for collaborative development.

3.3 Use Scientific Research Training and Practice as a Link

Focusing on engineering project practice, the program primarily aims to cultivate postgraduate students' innovative and practical abilities. It primarily targets enterprises and research institutes, focusing on engineering innovation design, new technology research and development, etc. This approach broadens the students' horizons, fosters their active practical awareness, and comprehensively enhances their comprehensive analysis, induction and summarization, as well as their innovation and entrepreneurship abilities.

4. The Reform and Practice of the "Four-in-One" Model

In the exploration of postgraduate innovation capability cultivation, a "four-in-one" reform and practice is carried out focusing on four core factors: teaching reform, scientific research platform, mentor team, and feedback mechanism. This approach truly provides theoretical basis, hardware support, knowledge support, and positive feedback incentives for enhancing postgraduate innovation capability cultivation. The idea is illustrated in Figure 2.

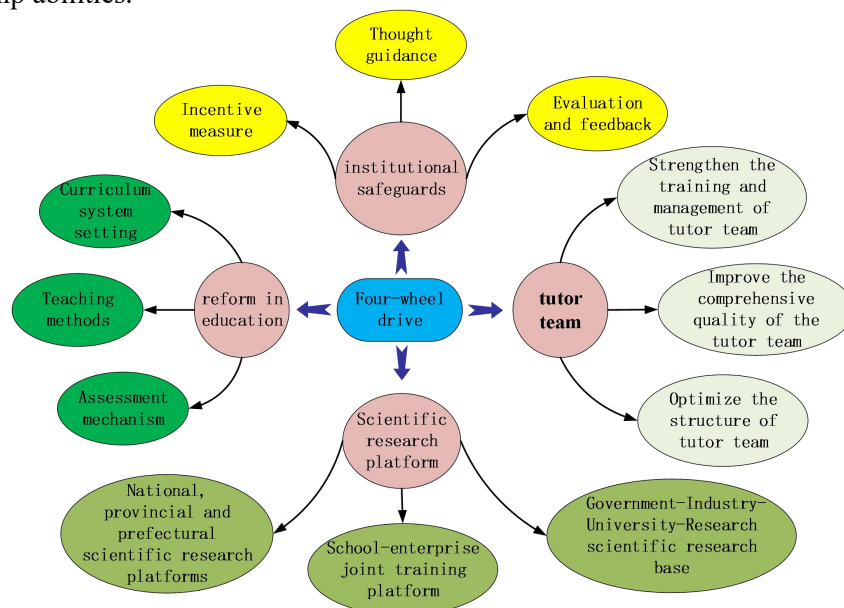


Figure 2. Graduate Research Platform

4.1 Teaching Reform

The traditional teaching mode is outdated and the teaching methods are archaic, which is not conducive to stimulating students' innovative potential [10,11]. Graduate education reform is a core focus in cultivating high-level composite talents. It requires collaborative advancement in three dimensions: curriculum design, teaching methods, and assessment mechanisms, to establish an educational system that aligns with both societal needs and individual development. Curriculum design is the core carrier on talent cultivation. While maintaining a balance among its foundation, expertise, and related elements, it is necessary to improve its overall, cutting-edge, and comprehensive nature. On one hand, it is necessary to establish a solid foundation on disciplinary knowledge to ensure the depth and systematicity of professional courses. On the other hand, disciplinary barriers should be

broken down to promote interdisciplinary integration, by introducing interdisciplinary modules such as bionics and artificial intelligence. It is indispensable to meet the demand for composite talents in society by promoting the integration and complementarity of knowledge in different fields. On other hand, for graduate students with special talents, personalized training mechanisms should be established. Graduate students are allowed to customize course packages based on their research interests and career aspirations. Graduate students should have the right to choose cutting-edge topics outside of core courses, to truly embody the principle of personalized teaching.

The teaching methods should be reformed by problem oriented and abandoning the traditional indoctrination teaching model. It is recommended to widely adopt case-based teaching, discussion based teaching, and guided

teaching, combined with various forms such as special lectures, literature research, and social practice. It is indispensable to stimulate the positive thinking ability of graduate students. For example, real part design cases can be introduced into mechanical design courses, and production internships can be introduced into manufacturing technology foundation teaching, so that graduate students can deepen their theoretical understanding through practice and improve their ability to solve practical problems. At the same time, graduate students are encouraged to independently carry out research projects, cultivate research literacy and innovation ability through literature review, team collaboration, and achievement reporting. The assessment mechanism should emphasize competency-based orientation and establish a diversified evaluation system. It is necessary to abandon the single written examination mode and implement diversified assessment forms such as comprehensive course design, special topic papers, innovative works, and reading reports, focusing on assessing graduate students' abilities to identify, analyze, and solve problems. For example, course grades can be decomposed into multiple dimensions such as classroom discussion performance, quality of research reports, and group project outcomes, to comprehensively evaluate the comprehensive literacy of graduate students. At the same time, a mechanism combining process evaluation and summative evaluation should be established, paying attention to the growth and progress of graduate students in the learning process and guiding them to shift from "exam-oriented learning" to "competency-based development".

4.2 Scientific Research Platform

In the rapidly developing field of mechanical engineering, graduate student training needs to break free from the limitations of traditional classrooms and achieve a deep integration of theory and practice [12]. Adhering to the core principle of "based on the region, oriented towards the industry, relying on enterprises, and fostering collaboration between schools and enterprises", our school integrates the teaching and research strengths of the university with the engineering advantages of enterprises. In conjunction with the mechanical engineering graduate student training program, we have diligently established a "three-in-one" practical innovation base, consisting of an on-campus

practical education base, a joint training platform between schools and enterprises, and a government-industry-university-research cooperation research base. This lays a solid foundation for cultivating mechanical engineering graduate students who possess both solid theoretical knowledge and exceptional innovation abilities.

The on-campus practice base is the core platform for graduate students to consolidate their theories and carry out fundamental research. There are three provincial-level platforms: the "Electromagnetic Equipment Design and Manufacturing Key Laboratory," the "Fuel Cell Technology Engineering Research Center," and the "Complex Structure Topology Innovation Design and Manufacturing Engineering Research Center" in Hunan Province. These platforms have advanced experimental equipment and professional research teams. The research field covers multiple cutting-edge areas such as electromagnetic equipment development, breakthroughs in fuel cell technology, and complex structural design. Basic theories can be verified and in-depth research are conducted on key technologies here. Classroom knowledge is transformed into practical research abilities. For example, in the Electromagnetic Equipment Design and Manufacturing Key Laboratory, graduate students participate in high-end electromagnetic equipment research. They engage in the entire process from principle design to prototype trial production to gradually master core technologies in the field of mechanical engineering.

The school-enterprise joint training platform is a crucial link between campus and industry. A deep collaboration has been established between industry leaders Hunan Kemeida Electric Co., Ltd. and Hunan University of Science and Technology. A Fuel Cell Co. Ltd. is established for a training platform that precisely aligns with industry needs. Technical challenges and R&D projects are introduced from actual production into the training system. Graduate students, through internships in enterprises and participation in project research, directly face industry pain points and learn advanced engineering technology and management experience from enterprises. Hunan Kemeida Electric Co., Ltd., with rich engineering practical experience in electromagnetic equipment manufacturing, allows graduate students to participate in product upgrade and

transformation projects after settling in, applying laboratory research results to actual production, achieving seamless integration of theory and practice. Hunan University of Science and Technology Fuel Cell Co., Ltd. provides graduate students with practical scenarios for the industrialization of fuel cell technology, helping them grasp the cutting-edge developments in the industry.

The government-industry-university-research institute (G-I-U-R) scientific research base serves as a crucial engine for enhancing the innovation capabilities of graduate students. Our institute actively collaborates with the government, enterprises, and research institutes to jointly establish engineering centers and joint research and development bases. Leveraging government policy guidance and resource coordination, we integrate high-end research resources from research institutes with the industrialization capabilities of enterprises, focusing on addressing major needs in the development of the regional mechanical engineering industry and conducting joint research. On this platform, graduate students can participate in cross-disciplinary and cross-subject research projects, gain exposure to cutting-edge research concepts and technological methods, and develop the ability to solve complex engineering problems. Additionally, the G-I-U-R scientific research base provides a channel for graduate students to transform their research achievements, ensuring that innovative results are truly implemented and achieving the leap from the laboratory to industrial application. Through the collaborative efforts of the "Trinity" Practical Innovation Base, our institute will comprehensively enhance the engineering application and practical innovation abilities of mechanical engineering graduate students, and cultivate high-quality and versatile professionals for the development of the regional mechanical engineering industry.

4.3 Mentor Team

To enhance the innovation and practical abilities of graduate students, it is imperative to strengthen the construction of the mentor team. Firstly, optimize the structure of the mentor team. It is essential to improve the selection mechanism of mentors, emphasizing not only academic ability and attainments but also academic ethics and integrity. Vigorous efforts should be made to cultivate young and middle-

aged scholars with a broad knowledge base, a spirit of continuous improvement, and a decent academic style, achieving a mentor team with a reasonable age gradient. Secondly, enhance the overall quality of the mentor team. Strengthen the introduction, training, and exchange of mentors through multiple channels and avenues. Arrange for mentors to participate in training courses for graduate mentors within the province in a planned manner, organize mentors to study and research at domestic and foreign universities, enhance their theoretical level, and grasp the frontier directions of discipline development. Deepen their training in scientific research institutions or enterprises for job transfer and practice, improving their practical ability and ability to solve practical problems. Try to implement mentor sharing among different universities, or hire well-known scholars, professors, enterprise executives, government officials, and professionals with certain theoretical and practical levels from other departments to serve as mentors or part-time mentors. Thirdly, strengthen the management and assessment of the mentor team. Conduct comprehensive, scientific, and fair assessments of various aspects of the cultivation process, stage achievements, thesis quality, and personal ability improvement of graduate students. Comprehensively evaluate the personal cultivation, professional academic ability, and level of mentors during their tenure, and implement a regular evaluation and appointment system.

4.4 Feedback Mechanism

The quality of graduate training is a core indicator for measuring the level of higher education. Its improvement is a systematic project that relies not only on external support such as disciplinary foundations, scientific research resources, and academic ecology, but also on institutional guarantees such as training programs and feedback mechanisms. Furthermore, it requires the collaborative efforts of both teachers and students.

The foundation of disciplines is the cornerstone of graduate student cultivation. First-class disciplines can provide cutting-edge theoretical systems, comprehensive knowledge frameworks, and profound academic accumulations, establishing a "knowledge coordinate system" for graduate students to grow. On this basis, scientific research projects become a "training

ground" for cultivating innovative abilities. By participating in national-level major projects and horizontal industry-university-research projects, graduate students are able to directly face scientific problems or industrial demands, honing their abilities to identify, analyze, and solve problems in practice. A strong academic atmosphere serves as the "soil" nourishing innovative thinking. Regular academic lectures, interdisciplinary discussions, laboratory group meetings, and other activities can broaden the academic horizons of graduate students, stimulate intellectual collisions, and cultivate their critical thinking and academic insight.

Topic selection and guidance are crucial aspects of graduate student cultivation. Accurate topic selection should not only be based on the forefront of the discipline but also align with national strategies or social needs, providing a clear direction for research work.

An excellent mentor is a "guide" for graduate students. The academic character and research literacy of graduate students are directly affected by his academic achievements, research experience, and educational philosophy. At the same time, the self effort of graduate students is the intrinsic driving force to improve the quality of training. There are core elements for transforming external resources into personal abilities, such as Positive literature review, rigorous experimental design, and persistent exploratory spirit.

Institutional guarantees for graduate education is provided by the scientific training plan and feedback mechanism. theoretical teaching and practical training are balanced in training program . A progressive curriculum system is established, consisting of "fundamental theories, cutting-edge methods, and practical applications". The entire training process should be integrated throughout in the feedback mechanism. It is necessary to timely identify problems and adjust direction through mid-term evaluations, academic reports, and mentor interviews to ensure controllable and adjustable training quality.

In the process of cultivation, it is the core logic to improve quality by the dialectical unity of theory and practice. On one hand, it is necessary to solidify the theoretical foundation. A "theoretical weapon" is provided for practical innovation by guiding graduate students to understand scientific principles and research methods from classical theories.

On the other hand, practical training should be strengthened, transforming theoretical knowledge into scientific research achievements through activities such as experimental verification, engineering trial production, and social research, striving to achieve breakthroughs in key indicators and core data. The achievements obtained in practice can further nurture theoretical innovation, distill new research mechanisms and laws, provide universal theoretical guidance for solving similar problems, and ultimately form a virtuous cycle of "theoretical accumulation - practical innovation - theoretical sublimation".

5. Conclusion

Through nearly three years of practice, this project has established one school-level scientific research platform and two school-enterprise cooperative talent training bases. It fully utilizes enterprise resources to cultivate students' engineering practical abilities, enhance their comprehensive strength, and has achieved significant talent cultivation benefits, winning social recognition and high praise. Students majoring in mechanical engineering have completed two provincial-level research and innovative experimental projects for college students, obtained four national patents, published 150 scientific research papers, won more than 30 national-level awards in academic competitions, including two at the national level, and participated in 16 teacher-led scientific research projects. The project achievements have won one second prize of the Hunan Provincial Teaching Achievement Award. The employment rate of our school's master's degree students in mechanical engineering and master's degree students in mechanical engineering is 98%, and the enrollment rate is 20%. Employers have responded positively.

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