Research on Comprehensive Evaluation System for Mechanical Engineering Postgraduates in Promoting Scientific Research and Innovation Ability

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Abstract. In the new era how to improve the scientific research and innovation capabilities of senior talents required by enterprises' scientific research innovation is the focus of the reform of engineering graduate education in universities. The postgraduate education has entered a connotative development stage that emphasizes structural optimization and improvement of scientific research and innovation capabilities. Comprehensively improving the scientific research and innovation capabilities of graduate students has become the core task of the current graduate education reform and development. At the critical stage, how to evaluate the comprehensive quality of graduate students that reflects the ability of scientific research and innovation is currently an important content. This paper studies various factors that affect the comprehensive quality of graduate students, follows the principles of scientific and feasibility, and builds a comprehensive quality evaluation system for postgraduate training based on scientific research and innovation capabilities to meet the requirements of social development. The weight of each influencing factor in the evaluation system is analyzed quantitatively, and the objective function model is constructed. Through the objective model function, an effective quantitative evaluation conclusion can be obtained. The research results show that the evaluation system not only meets the requirements of the society for talent training, but also can standardize graduate training through evaluation, encourage various training units to increase investment in graduate education, and promote the multi-dimensional construction of disciplines, training mechanisms, and organizational structures. The evaluation system has important reference significance for graduate training units in the evaluation of graduate education, the development of disciplines, the development of training programs that reflect the research and innovation ability of graduate students, and the setting of curriculum systems, etc.

Keywords: Mechanical Engineering, Scientific Research and Innovation Ability, Postgraduate Training Mode, Comprehensive quality evaluation

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1 Introduction

In recent years, our country's graduate education has moved from an extensional development stage that emphasizes on quantitative growth and scale expansion to a connotative development stage that emphasizes on structural optimization and the improvement of scientific research and innovation capabilities. Comprehensively improving the scientific research and innovation capabilities of graduate students has become the core task of the current graduate education reform.

Current research on the evaluation of graduate education quality focuses on graduate management models or on analyzing relevant factors that affect the quality of graduate education to propose policy recommendations, while research on the construction of a graduate education quality evaluation system in the improvement of scientific research and innovation capabilities is less. It is of great significance to improve the quality of postgraduate training1 to construct a set of graduate education quality evaluation system based on scientific research and innovation ability, to realize the quality evaluation of graduate education in the realization of scientific research, social services, cultural inheritance and innovation, international exchanges and cooperation, etc, it not only meets the requirements of the society for talent training, but also regulates graduate training through evaluation, encourages various training units to increase investment in graduate education, promotes the multi-dimensional construction of disciplines.

2 Postgraduate training model to promote scientific research and innovation ability

The postgraduate training to improve the scientific research and innovation capabilities is carried out in accordance with the three target modules of theoretical teaching, innovative project training, and scientific research practice. It follows the gradual advancement of innovation guidance, innovative practice and innovative research combining with the theoretical study, professional practice and scientific research practice according to the gradual training model, in the process of postgraduate training, the goal of scientific research and innovation practice are always focused on to carry out training in all stages. The cultivation system is shown in Fig.1.

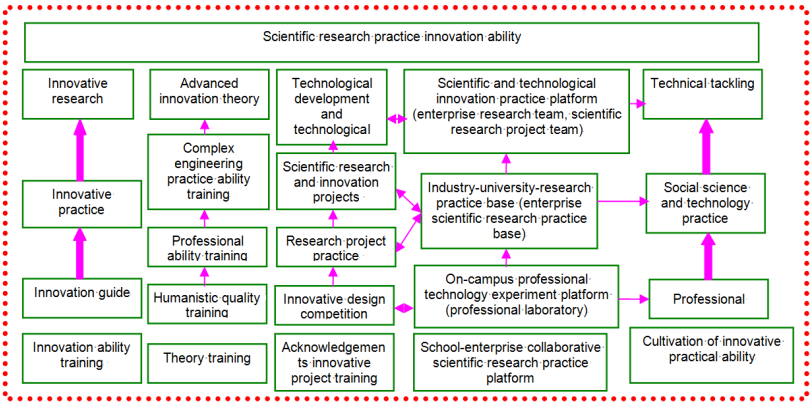

Fig. 1. Postgraduate training system to promote scientific research and innovation (Source:Owner-draw)

3 Analysis on the current situation of postgraduate comprehensive quality evaluation

The current graduate education quality evaluation system of our graduate training units is not sound, each training unit lacks a systematic comprehensive quality evaluation system for graduate students2, there are some problems3:(1) The assessment and evaluation system for postgraduate teaching is not comprehensive and the evaluation index for scientific research and innovation ability is lacked.(2) The current postgraduate graduation assessment system has some problems: emphasis on English proficiency and scientific research results, difficulty in evaluating the ability, vague assessment standards and grading methods, excessive power of tutors, and incomplete supervision mechanisms, etc.(3) The evaluation system is too general and lacks pertinence. At present, for the quality evaluation of graduate students cannot truly reflect the objectivity and rationality of the evaluation, and cannot truly reflect the current level of graduate education, and it is also easy to homogenize the educational model.

4 The construction of comprehensive quality evaluation system for postgraduates to improve its scientific research and innovation ability

4.1 The comprehensive quality evaluation model of postgraduates to improve the ability of scientific research and innovation

The ultimate goal of evaluating the quality of postgraduate education should be the ability of postgraduates to have scientific research and innovation qualities to serve the society3. Therefore, to design a dynamic and diversified assessment system that is not too complicated and has strong operability and reflects the training requirements of

graduate students' scientific research and innovation ability is an urgent issue. Several principles should be followed in constructing a comprehensive quality evaluation system:① Must following the laws of education and national norms; ② The combination of qualitative evaluation and quantitative evaluation should be fully considered to grasp the quality of graduate education as a whole; ③ It involves not only the evaluation of graduate students themselves, but also the evaluation of graduate training conditions, including the construction of the tutor team of the graduate training unit, discipline construction, student types, experimental conditions, public service platform construction, etc.④ It is necessary to fully consider the previous learning experience of graduate students, including the academic background, professional background, and undergraduate academic performance of graduate students, and take the past learning experience and performance of graduate students as important reference indicators.

The comprehensive quality of graduate students is decomposed into three indicators of input quality, process quality, and result quality for evaluation. Input quality mainly refers to the type of students, including the type of student source, professional background and undergraduate study status. Process quality includes three aspects: influencing factors, course learning and scientific research process. The influencing factors include resources and environment, teaching staff and evaluation of discipline construction. The evaluation of the scientific research process includes the status of the scientific research process, the evaluation of scientific research achievements and the evaluation of graduation thesis. The output quality of graduate students also includes the professional ethics of graduate students, the ability to serve society, the spirit of scientific research, and the status of work and salary. The model of its comprehensive quality evaluation system is shown in Fig.2.

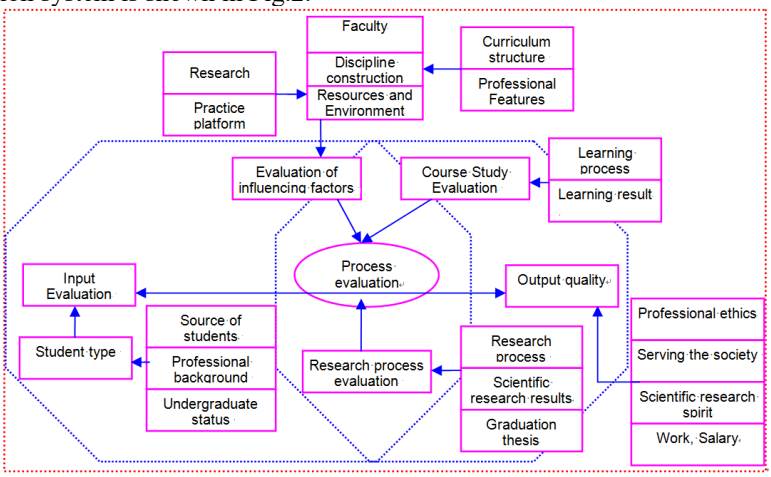

Fig. 2. Comprehensive quality evaluation model of postgraduate cultivation in the whole process (Source: Owner-draw)

4.2 Constructing the objective function of comprehensive quality evaluation in the postgraduate training process

According to the comprehensive quality evaluation system of graduate education, we can clearly understand the internal issues that affect their own quality, such as the initiative of the graduate students to affect their own abilities, and whether the tutors and academic organizations play a role in educating them, etc. Paying more attention to the subjectivity, quality process formation and personality development of graduate students4, the formation of graduate students' innovative ability is mainly reflected in their initiative and the process of continuously solving problems. Therefore, it is an important role in promoting the talent and development of graduate students to pay attention to the quality appreciation of graduate students' knowledge, abilities and qualities in the training process or in each training link.

According to the comprehensive quality evaluation model of postgraduate training in the whole process, each evaluation factor in the model is classified into two-level and three-level evaluation index, and each evaluation index is quantitatively scored, and then comprehensively scored of a single graduate student according to the weighting factor is gotten (shown in Table 1).

Table 1. Comprehensive quality evaluation goal and weight factor in the process of graduate training (Source: Owner-draw)

First-level indicators	Secondary indicators	Three-level indicators	Evaluation factors	Weights factor
Student type	Source of students	Student status	Classification and quantification of the student source school(A_1)	w_1
	Professional background	Professional background	Classification and quantification of professional background(A_2)	w_2
	Undergraduate status	Undergraduate status	Quantify by undergraduate comprehensive grade point(A_3)	w_3
Resources and Environment	Research platform	Research platform	Quantify of scientific research platform(A_4)	w_4
	Practice platform	Practice platform	Quantify according to the level of practice platform(A_5)	w_5
Discipline construction	Curriculum structure	Curriculum structure	Quantify according to the professional curriculum system(A_6)	w_6
	Professional Features	Professional Features	Quantify according to whether it has industry characteristics(A_7)	w_7
Faculty	Faculty	Faculty	The status of the construction of the faculty(A_8)	w_8
Course learning	Learning process	Learning ability	Ability to learn new knowledge(A_9)	w_9
	Learning result	Theoretical knowledge	Course learning and skill mastery(A_{10})	w_{10}
Research process	Research process	Research project	Ability to carry out scientific research projects(A_{11})	w_{11}
		Research practice	Independence in the process of scientific research practice(A_{12})	w_{12}
	Scientific research results	Academic papers	The quality and quantity of published research papers(A_{13})	w_{13}
		Academic exchange	Participate,organize,report (A_{14})	w_{14}

Output quality		Intellectual property rights	Authorized patents or other intellectual property rights(A_{15})	w_{15}
		Achievement transformation	Patent or other intellectual property conversion(A_{16})	w_{16}
		Thesis Proposal	Proposal report and reply results(A_{17})	w_{17}
	Graduation thesis	External review of papers	Average score of external review of paper(A_{18})	w_{18}
		Graduation reply	Graduation reply results(A_{19})	w_{19}
	Professional ethics	Professional ethics	Whether to violate professional norms and ethics(A_{20})	w_{20}
	Scientific research spirit	Research awareness	Sensitivity and interest in scientific research(A_{21})	w_{21}
		Research attitude	The emphasis on scientific research(A_{22})	w_{22}
		Scientific perseverance	Perseverance in scientific research(A_{23})	w_{23}
	Work, Salary	Work, Salary	Quantify according to the nature of work and salary(A_{24})	w_{24}
	Serving the society	Serving the society	Quantify social contribution within five years(A_{25})	w_{25}

Each quantitative score needs to be determined according to each training institution's own situation, and the weight factor needs to be set by each training institution according to its professional characteristics and training goals (for example, the quantitative standards of the indicators of the faculty are shown in Table 2).

Table 2. The quantitative standards of the indicators of the faculty (Source:Owner-draw)

	Classification index	**Evaluation factors**	**Weights factor**
Faculty （100）	The overall level (Weight h_1)	Proportion of PhD degree among tutors(B_1)	v_1
		Proportion of senior professional titles(B_2)	v_2
		Ratio of graduate students to tutors(B_3)	v_3
		Number of tutors violated academic ethics(B_4)	v_4
	Tutor performance (Weight h_2)	Number of papers published in core journals (B_5)	v_5
		Number of papers of international journals (B_6)	v_6
		The number of patents(B_7)	v_7
		The number of tutors received government-funded scientific research projects(B_8)	v_8
		The number of tutors' annual cooperative scientific research funds received by the company(B_9)	v_9
		Percentage of tutors received teaching achievement awards per year(B_{10})	v_{10}
		Percentage of tutors receiving scientific research achievement awards per year(B_{11})	v_{11}
		Average annual conversion rate of scientific research results (B_{12})	v_{12}
	International level	Percentage of tutors with overseas graduate degrees(B_{13})	v_{13}
		The proportion of tutors with six months of overseas study experience(B_{14})	v_{14}

	(Weight h_3)	The proportion of tutors with part-time jobs in overseas academic organizations(B_{15})	v_{15}
		Percentage of foreign tutors(B_{16})	v_{16}

According to Table 2, set the evaluation objective function of the faculty is $A_8 = g(B_a, v_a)$, then:

$$A_8 = g(B_i, v_j) = \sum_{a=1}^{16} B_a \times v_a \quad (1)$$

Where:

$$\begin{cases} \sum_{a=1}^{4} v_a = h_1, \sum_{a=5}^{12} v_a = h_2, \sum_{a=13}^{16} v_a = h_3 \\ h_1 + h_2 + h_3 = 1 \end{cases} \quad (2)$$

Set the objective function is $f(A_i, w_j)$, then:

$$f(A_i, w_j) = \sum_{i=j=1}^{25} A_i \times w_j, \sum_{j=1}^{25} w_j = 1 \quad (3)$$

4.3 Analysis of comprehensive quality evaluation indexes

(1) Evaluation of postgraduate course study

During the postgraduate course study stage, the effect of the course teaching is evaluated from the perspective of students' perception according to the degree of fit between the personal training plan and their own development needs5. The course assessment method can be improved from the following aspects: for more basic courses, evaluation by examination is adopted to ensure the quality of course learning. For courses submitting course essays, teachers should feed back the grading basis and revision opinions to students after revising the course essays, so that the graduate students have the opportunity to recognize their own shortcomings and make improvements. The assessment of teachers is strengthen in the course of teaching, feedback links are added in teaching, and the form of coursework spot checks and regular discussions is used to encourage teachers to continuously update teaching content, improve teaching methods, stimulate graduate students' research interest, and improve their learning efficiency. If the performance of graduate students in the research process does not meet the minimum requirements, they will not receive corresponding credits. According to the requirements of the course teaching objectives and the course teaching effect, the reflection of scientific research innovation indicators is put forward to, quantitative analysis of each evaluation index is carried out, and the course teaching achievement report as the basis for evaluating the teaching effect is submitted.

(2) Evaluation of practical teaching links to enhance graduate students' scientific research and innovation ability based on the school-enterprise cooperation platform

For engineering graduate education, the best engineering practice platform6 is provided by school and enterprise. Through the establishment of a school-enterprise cooperation platform, the enterprise technical backbones are introduced, and the enterprise engineering projects are participated in, a school-enterprise joint training model has

been formed. The main measures are: To establish enterprise postgraduate workstations to create a new platform for engineering talent training, high-level corporate technology backbones are introduced to guide postgraduates in innovative practice, and to participate in actual engineering projects, etc.

The evaluation of practical teaching links focuses on strengthening students' perception experience in practical training. It is necessary to inspect the effect of practical training to consider all parties involved in "teaching" and "learning" such as teachers, students, and engineers in the practice training base. In the selection of evaluation indicators, first of all, we need to examine from the perspective of the main body of the students' practical training such as the students' awareness and the ability to solve problems continuously, as well as the spirit of cooperation and organizational skills embodied in the process of practical training. The second, it needs to be evaluated from the fit of the various carriers provided, such as whether the practical courses closely follow social needs, whether they can be adjusted in time according to changes in social needs, whether the practice base and training platform meet the needs of students' growth, and whether they can be based on professional development needs to set up special practice content, and whether the mode and method of student participation in practice training can help students enhance their awareness of participation and independent thinking ability, etc. At the same time, the "characteristic" individual evaluation indicators for universities and various disciplines are provided to embody characteristic practical courses, characteristic vocational skills training methods and effective practical ability training models to promote the universities to form its own characteristics and advantages in the practical training stage of graduate students.

Constructing a practical quality evaluation index for postgraduate training, it is mainly from four aspects such as platform conditions, operation management, process monitoring, and practical effects to construct a graduate education practice platform to build a quality evaluation index system.

(3) Practice assessment and evaluation of scientific research projects

In the process of cultivating the scientific research ability of graduate students, a scientific research information database should be established to collect research process information and research results information7. Evaluation indicators should be considered not only comprehensive factors such as graduate students' learning ability, practical ability, innovation ability, teamwork ability, etc., but also the completion of scientific research projects, academic achievements, and technical achievements. Evaluation indicators can be divided into scientific papers (number of papers published, journals published, number of citations) and patents, etc. Scientific research projects can be evaluated from multiple aspects such as quantity and quality.

(4) Evaluation of graduation thesis guidance process and graduation defense process

The dissertation is the final result that needs to be submitted before graduation, and its formation process generally include thesis proposal, mid-term inspection, pre-defense, peer review, and formal defense. It is believed8 that strengthening academic ethics and normative education, innovative talent training mode, and supervisor guidance performance appraisal mechanism in the process management link can improve the quality of the dissertation. It is believed9 that measures such as establishing norms to strengthen pre-review and blind review, and clarify the responsibilities of all parties

should be adopted to realize the process control of thesis quality. A reasonable evaluation standard for thesis quality can be established from the three links of unified evaluation, different training goals, and the thesis process management: ① The principle of unified evaluation is adhered to: the assessment indicators for paper quality evaluation under the same discipline and training form should be unified, and different experts should quantitatively evaluate the quality of papers under the same standard, and try their best to be fair and objective. ② Difference of factors need to be considered in the evaluation of thesis quality according to the difference between academic and professional postgraduate training objectives, and then the thesis quality evaluation index is set reasonably. ③ Incorporate the process management link of thesis into the category of thesis quality evaluation.

5 Conclusions

The construction of a postgraduate training quality evaluation system in universities is of great significance. It provides positioning information for the competition and development of postgraduate training units, provides quantitative analysis indicators for all sectors of the society to understand the quality of university graduate training and its scientific research and innovation capabilities, and provides guides for the majority of candidates to choose schools for postgraduate entrance examinations, etc. Through the comprehensive quality evaluation system of graduate research and innovation ability, the comprehensive quality evaluation of graduate student training can be effectively carried out. The results have important significance for graduate education evaluation, discipline development, development of graduate research and innovation ability training plan, curriculum system setting, etc.

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7 References

1. QI Kai,GUAN Ying,ZHAO Chen- guang. A Study of Graduate Education Quality Evaluation System under the Background of "Internet+education" [J] Teaching Forum,2019,5,No.19:184-186.

2. YING Shuang,KANG Jun,ZHEN Liang. Establishing and Objective System for the Evaluation of Quality of Graduate Education[J].Journal of Graduate Education,2015,8,No.4:58-62.
3. WEI Hong, ZHONG Bin-lin. Attach importance to students' learning effects and improve the effectiveness of educational evaluation[J].China Higher Education Research,2009(10):13-15.
4. LUO San-gui. An Analysis of the Reform Characteristics of Innovative Talents Training Mode in Colleges and Universities from the Perspective of Independent Innovation[J]. Chinese University Teaching,2013(5):12-15.
5. GEN You-quan. On the Construction of "Four in One" Postgraduate Course Teaching Evaluation Mechanism[C]. The 7th National Engineering Graduate Education Work Seminar,GuiLin,2013:83-88.
6. OUYANG Hai-bo,HUANG Jian-feng,LI Cui-yan, etc.Local University Graduate Student Innovation Ability Training Mode of Multiple Cooperative Exploration and Practice[J], Education Teaching Forum,2018(15):118-120.
7. GUO Xiao-qing,JIANG Hai-yan. Probe into the Quality Control Mechanism of Professional Dissertations—Taking the Professional Degree Program of Agricultural Informatization as an Example [J]. University Laboratory Science and Technology,2019(1):127-128.