Research on the Construction of a Comprehensive Evaluation System Based on Competence Cultivation for Graduate Students in Materials and Chemical Engineering

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Abstract: Materials and Chemical engineering has expanded into interdisciplinary fields such as energy, environment, biology, materials, electronics, and information. This expansion has increased the complexity of Materials and Chemical engineering problems and raised the demand for highly skilled professionals. To meet this demand and ensure the cultivation of high-quality applied talent, the construction of a scientifically sound comprehensive evaluation system for graduate students is particularly important. This paper focuses on graduate students in the field of Materials and Chemical Engineering and proposes a competency-based evaluation indicator system. This system, crucial in meeting the demand for high-quality applied talent, integrates the requirements for comprehensive development in moral, intellectual, physical, aesthetic, and labor aspects, and designs evaluation indicators weighing from the perspectives of students' personal development and institutional management. As well as, a tripartite comprehensive training strategy is proposed, which involves shaping values, imparting knowledge, and developing competencies. It can comprehensively and scientifically assess the comprehensive abilities and qualities of graduate students, and meet the demand for applied talents in the field of materials and Materials and Chemical engineering. Through this approach, the graduate students' moral qualities, knowledge levels, and practical abilities have been cultivated well; thereby their competitiveness is enhanced in the field of Materials and Chemical Engineering. The interdisciplinary advantages of Materials engineering and Chemical engineering have been fully utilized, and a group of high-level applied talents who possess both moral character and capability have been cultivated by using the comprehensive evaluation of graduate students as the guiding principle, which provides talent support for the transformation, upgrading, and innovative development of the chemical new materials industry. These achievements fully demonstrate the effectiveness of the evaluation methods we provide and have certain reference values for graduate education. This study constructs a competency-based comprehensive evaluation system for graduate students in Materials and Chemical Engineering, combining students' individual development with the discipline's management. Due to the limitations of objective conditions, the project team will need to explore and research further in the next stage to optimize the accuracy of evaluation indicators and the weight allocation between different disciplines, as well as promote graduate student classification development through evaluation.

Keywords: Materials and Chemical Engineering; Postgraduate; Evaluating Indicator; Evaluation System; Competence Cultivation

1. Introduction

Energy, food, and materials are the foundation for human survival and development. Technological advancements in chemical

engineering, metallurgy, and materials have played a crucial role in the evolution of human civilization [1]. The chemical industry is one of the critical pillars of national economic development, and materials science is closely related to people's lives. The cultivation of relevant talents plays an essential role in the current social development [2]. Postgraduate education is the primary way to cultivate high-level innovative talents. In the new era, comprehensively improving the quality of postgraduates has become the core task of building a strong nation. The National Graduate Education Conference in 2020 pointed out that the core of comprehensive development education for graduate students is "moral, intellectual, physical, aesthetic, and labor" education, and the daily cultivation of graduate students should revolve around this core [3-4]. The Ministry of Education has adjusted the professional categories of Materials Engineering and Chemical Engineering to Materials and Chemical Engineering. It's high time to make good use of its cross-disciplinary advantages and cultivate high-level applied talents to provide strong talent support for the transformation and upgrading of national industries and innovative development [5]. In this context, the traditional education mode and evaluation system can hardly meet the needs of cultivating high-quality applied talents. Therefore, it is essential to construct a scientifically sound comprehensive evaluation system for graduate students. This paper focuses on graduate students in Materials and Chemical Engineering. It proposes a competency-based evaluation indicator system that integrates the requirements for comprehensive development in moral, intellectual, physical, aesthetic, and labor aspects and researches the personal development of postgraduates and the management of disciplinary talent cultivation.

2. Research Status

The research on the construction of the evaluation system of domestic college students' all-round development is mainly carried out from some specific angles, such as national identity, learning ability [6], collaborative development, and so on, to analyze the connotation of the evaluation system. Fan et al. comprehensively evaluated college students' overall development based on ideological and moral quality, scientific and cultural quality, physical and mental health quality, inventive and creative quality, labor quality, etc. They established an evaluation system containing 17 secondary and 41 tertiary indicators [7]. However, the evaluation indicators failed to fully reach "moral, intellectual, physical, aesthetic and labor requirements." Zhang et al. proposed an evaluation system framework with five primary indicators, 12 secondary indicators, and 33 tertiary indicators, which includes all aspects of moral, intellectual, physical, aesthetic, and labor [8]. The evaluation system combines quantitative evaluation and qualitative description to evaluate students' development more comprehensively and objectively.

The above research on the evaluation index of undergraduate students' cultivation is a good enlightenment and reference for graduate students' cultivation. Based on the value concept of collaborative governance, it has established a distinctive evaluation system of graduate education characterized by multiple implementation subjects [9]. Domestic colleges and universities have steadily advanced the reform of the higher education evaluation system, diversifying social evaluation, gaining support from the legal system, increasing the autonomy of the internal evaluation system of universities, and focusing on students' participation in the review to achieve the modernization of higher education governance [10].

Domestic evaluation of graduate education mainly involves classification as orientation, measurement level as the goal, normative reference as the benchmark, and mixed research as the method. Future research will explore the evaluation index system, combining multiple subject evaluations, commonality, and individuality, and promote the virtuous circle of process evaluation and result feedback [11]. Domestic scholars have researched the comprehensive quality evaluation system of postgraduates. For example, Guo et al., from the perspective of materialistic dialectics, believed that the comprehensive quality evaluation index system of postgraduate students should follow the principles, including the combination of comprehensiveness and relevance, qualitative

analysis and quantitative analysis, feasibility and sustainability [12], the combination of political and academic evaluation, qualitative and quantitative evaluation, positive and negative evaluation, general and special evaluation, individual evaluation and overall evaluation [13], the combination of complete evaluation, comprehensive evaluation, formative and summative evaluation [14] and other views. Using the Analytic Hierarchy Process or Fuzzy Mathematics, Zhang et al. constructed a thorough quality assessment system and evaluation model for postgraduate students with multiple quantitative indicators in terms of ideology and ethics, scientific research and professionalism, practical ability, essential qualities, and demerit items [15-17]. Chen et al. evaluated ideological and moral quality, academic and scientific research quality, social practice quality, professional competition quality, innovation quality, and physical and mental quality. They obtained the corresponding third and fourth-level assessment indexes [18-19]. Deng put forward a "six-dimensional integration" developmental evaluation system that includes the dimensions of ethics education, intellectual education, physical education, aesthetic education, physical education, and competence, with the AHP algorithm to assess the weights of the dimensions and evaluation indexes; he conducted diagnostic analyses of the evaluation results to form a "physical examination report" of the students [20].

Postgraduate education and management face new challenges, mainly in the following aspects. First, the evaluation of the comprehensive quality of postgraduates focuses on individual evaluation of postgraduates. It ignores the overall assessment on the discipline or school level, resulting in a lack of supervision of the faculty guidance, which makes it difficult to point out the direction of the quality improvement of students. Second, there exist differences in the degree of importance of moral, intellectual, physical, aesthetic, and labor, and the evaluation methods among different colleges and disciplines lack consistency in the evaluation standards and procedures. Third, due to the discrepancies in postgraduate backgrounds, professional fields, and research directions, it is difficult to fully quantify the evaluation of moral, intellectual, physical, aesthetic, and labor education. Lastly, engineering awareness needs to be emphasized in cultivating engineering graduate students. Suppose the cultivation of engineering awareness of graduate students is not in place in the teaching. In that case, it will likely lead to poor adaptability of graduate students after graduation, insufficient capability to work in the real world, weakness in cooperation and communication, and lack of innovative consciousness [21-22]. Therefore, the above problems and deficiencies become the starting point of this paper.

3. Postgraduates' Comprehensive Quality Evaluation Index System in the Field of Materials and Chemical Engineering Based on Competence Cultivation

The cultivation of talents in colleges and universities has always been the focus of attention in the education sector. With the development and progress of society, cultivating college talents with comprehensive quality has become the demand of the times. In this context, MIT believes that the new engineering education should pay more attention to cultivating students' thinking [23]. The research shows that the interviewed teachers believe that postgraduate students should possess the five most important abilities [24], which is consistent with the educational philosophy advocated by the state. In order to ensure the effectiveness of the evaluation system, the design of the evaluation system and its indicators should consider the physical and mental characteristics and training requirements of graduate students. In materials and chemical engineering, the cultivation objectives of postgraduates are adjusted with the constant change in demand for industrial talent. To maintain the adaptability of the evaluation system, it is necessary to keep it up-to-date by adjusting the parameters of the indicators. The comprehensive evaluation system for postgraduates constructed in this paper starts from the two dimensions of students' personal development and college management. It combines the five aspects of moral, intellectual, physical, aesthetic, and labor to assess postgraduates' overall quality and ability comprehensively. The evaluation index of personal development focuses on the micro requirements of graduate students, including

moral cultivation, cultivation of innovation ability, improvement of practical ability, development of teamwork ability, and cultivation of lifelong learning ability. The evaluation index of college management focuses on the macro requirements of postgraduates, including the quality of teaching resources, academic atmosphere, nurturing the postgraduates in social practice, base collaboration, and exchange and cooperation. These two aspects complement each other and serve the work of graduate education, promoting the integration and development of engineering education and industry and cultivating high-level applied talents who can solve complex engineering problems in materials and chemical engineering. Please refer to Tables 1 and 2 for specific evaluation contents.

The above table clearly shows the indicators and weights of the evaluation system. However, the following aspects must be noted when implementing the evaluation system for materials and chemicals postgraduate students. Firstly, the emphasis on cultivating graduate students' qualities varies across stages. In the initial stage of graduate education, the focus should be on acquiring disciplinary knowledge and developing foundational skills. In the intermediate stage, the emphasis should shift towards cultivating research and innovation capabilities while also encompassing comprehensive development in ethics, physical education, aesthetic education, and labor education. At the advanced stage, the emphasis should be on cultivating graduate students' independent research abilities, academic influence, and social responsibility.

Table 1. Contents and Scores of the Comprehensive Quality Evaluation Indicators of Graduate Students

Level 1 index P_i(weight W_i)	Secondary index P_{ij}(weight W_{ij})	Level 3 Indicators
Ethics Education Evaluation P_1(W_1=18%)	Ideological Quality P_{11}(W_{11}=30%)	(1) Correct outlook on the world, life, and values, e.g. awareness of renewable energy sources, etc. (2) Serious attitude to scientific research with an optimistic mind.
	Moral Trait P_{12}(W_{12}=30%)	(1) Social morality, e.g., awareness of environmental protection, etc. (2) Family virtues (3) Personal character
	Dedication education P_{13}(W_{13}=30%)	(1) Collective education (2) Conscious Discipline Education (3) Democracy and Law Education
	Competence Evaluation P_{14} (W_{14}=10%)	Representative achievements or deeds.
Intellectual Education Evaluation P_2(W_2=64%)	Academic Achievement P_{21} (W_{21}=50%)	(1) Course scores include courses such as Process Wastewater Treatment. (2) Paper scores, for example, research projects such as applying new materials to the chemical industry.
	Professional Quality P_{22} (W_{22}=20%)	(1) Professional knowledge in the Materials and Chemical engineering field, such as safety awareness in materials and chemical engineering practice. (2) Professional ability in the Materials and Chemical engineering field
	Practice and Innovation Literacy P_{23} (W_{23}=20%)	(1) Scientific research and practice ability, for example, practical materials and chemical engineering skills. (2) Academic innovation ability
	Competence Evaluation P_{24} (W_{24}=10%)	Representative achievements or deeds
Physical Evaluation P_3(W_3=6%)	Popularization of Sports Knowledge: P_{31}(W_{31}=20%)	(1) Knowledge lecture (2) Experience exchange (3) Knowledge competition
	Physical Skills Cultivation: P_{32} (W_{32}=20%)	(1) Minoring in sports programs (2) Participation in sports training (3) Skill qualification certificate
	Physical Practice Experience P_{33} (W_{33}=50%)	(1) Participation in sports interest groups, sports clubs, etc. (2) Participation in after-class exercise to strengthen the body (3) Participation in sports events on and off campus (4) Participation in national sports activities (5) Experience satisfaction evaluation
	Competence Evaluation P_{34} (W_{34}=10%)	Representative achievements or deeds
Aesthetic Education	Popularization of Aesthetic Education Knowledge P_{41}	(1) Knowledge lecture, for example, the aesthetics of craftsmanship and design in Materials and Chemical engineering.

Evaluation P_4(W_4=6%)	(W_{41}=20%)	(2) Experience exchange (3) Knowledge competition
	Aesthetic Education Skills Training P_{42} (W_{42}=20%)	(1) Minoring in aesthetic education projects (2) Participation in aesthetic education training (3) Skill qualification certificate
	Aesthetic Education Practice Experience P_{43} (W_{43}=50%)	(1) Listening to the forum of elegant art and art masters, and visiting art galleries, museums, and other public art places (2) Participation in the school art clubs, calligraphy clubs, etc. (3) Participation in the volunteer service of the art venues (4) Participation in art competitions, publicity activities related to intangible heritage, creation and exhibition of artistic works, etc. (5) Experience satisfaction evaluation
	Competence Evaluation P_{44} (W_{44}=10%)	Representative achievements or deeds
Labor Evaluation P_5(W_5=6%)	Popularization of Labor Knowledge P_{51} (W_{51}=20%)	(1) Knowledge lecture: to spread the concept of labor (2) Experience exchange (3) Knowledge competition
	Labor Skills Training: P_{52} (W_{52}=20%)	(1) Minoring in the labor projects (2) Vocational skills training (3) Professional qualification certificate
	Labor Practice Experience P_{53} (W_{53}=50%)	(1) Participation in being a teaching assistant or research assistant, volunteer service and other activities (2) Participation in off-campus practice base, visiting high-tech enterprises, public welfare labor, community governance, and other labor exercises, and experiencing the natural working environment of the Materials and Chemicals field. (3) Participation in the graduate student innovation and entrepreneurship competition (4) Participation in the daily services of the dormitory and laboratory (5) Experience satisfaction evaluation
	Competence Evaluation P_{54} (W_{54}=10%)	Representative achievements or deeds
Additional Indicator P_6	Extra Credit Index P_{61}	(1) There is no weight for the extra credit index (2) Graduate students who make special contributions or outstanding achievements in a certain level of index can add 0.5-2 points for each item (3) The maximum limit of additional points for this item is 10 points
	Point Deduction Index P_{62}	(1) There is no weight for the point deduction index (2) If graduate students have big mistakes in a certain level index with negative effects, 1-3 points will be deducted for each item (3) In case of big mistakes and serious adverse effects, the current annual evaluation is unqualified

Table 2. Contents and Scores of Graduate Evaluation Work Indicators by College

Level 1 indicators (weight)	Level 2 indicators (weight)	Level 3 indicators
Strong Foundation of Ethics Education P_1 (W_1=18%)	Postgraduate Courses P_{11} (W_{11}=40%)	(1) Colleges should offer the first lesson for new postgraduate students, select teaching materials within regulations, and strengthen the construction of teaching resources such as self-compiled teaching materials, reference books, and case studies. (2) Implementing the national requirements on course construction, exploring the education and competence elements contained in professional classes, and promoting the construction of graduate courses. (3) The number of course demonstration projects selected at the provincial level or above.
	Scientific Ethics and Academic Norms Education P_{12} (W_{12}=40%)	(1) Strengthening the publicity and education of scientific ethics and academic norms, guiding graduate students to adhere to academic integrity, and incorporating academic morals, ethics, and standards into the graduate cultivation plan as compulsory content. (2) Supervise the thesis writing and guide academic norms by supervisors. (3) Punishment of graduate students' academic misconduct.
	Postgraduate Practical Education P_{13} (W_{13}=20%)	(1) Organizing and carrying out social practice activities with various themes. (2) Organizing and giving full play to the role of graduate student associations and social organizations to make them an essential force in postgraduate education. (3) Awards for social practice to individuals or teams at provincial level or above.
The Innovation Cultivation Project of Intellectual	Construction of Excellent Postgraduate	(1) Scientifically formulating or revising the cultivation program, optimizing the curriculum system, learning advanced educational concepts, and actively exploring new educational modes, strategies, and paths.

Education P_2 (W_2=64%)	Teaching Resources P_{21}(W_{21}=35%)	(2) Compiling high-quality graduate teaching materials, attaching importance to the construction of teaching cases, and enhancing teachers' ability to combine theory with practice. (3) Selected graduate quality courses, cases, teaching materials, and educational reform projects at the provincial level and above.
	The Enhancement of Postgraduate Academic and Practical Innovation Ability P_{22}(W_{22}=15%)	(1) Fund graduate students to participate in top national competitions such as the China Graduate Innovation Practice Series Competition and "Internet +" College Student Innovation and Entrepreneurship Competition, as well as high-level professional competitions in the industry. (2) Undertaking provincial and above graduate innovation practice competitions, academic forums, and other activities. (3) Graduate students having obtained scientific research and practical achievements at or above the provincial level.
	Off-Campus Base Cooperative Education P_{23}(W_{23}=15%)	(1) Cooperation with high-level scientific research institutes and industrial enterprises. (2) Promoting the reform of training mode, attaching importance to the selection and recruitment of enterprise mentors, organizing school tutors to visit cooperative units to study, the status of joint training of graduate students in the base, and the effectiveness of talent cultivation. (3) The base is selected as a demonstration base at the provincial level.
	International Exchange and Cooperation in Education P_{24}(W_{24}=15%)	(1) Introduction and application of foreign high-quality educational resources. (2) Carrying out joint cultivation, cooperative scientific research, and laboratory co-construction with international high-level universities. (3) Funding for outstanding graduate students to participate in important international academic conferences and study visits.
	Typical Demonstration of the Tutor Teams P_{25}(W_{25}=20%)	(1) Select outstanding mentors and teams and typical models to play a demonstration and leading role. (2) Improving the tutor evaluation system, strengthening the education evaluation, and establishing the exit mechanism. (3) Being an excellent tutor or excellent team at the provincial level or above.
The Improvement Project of Physical, Aesthetic and Labor Literacy P_3 (W_3=18%)	Organization and Implementation of Physical Activities P_{31} (W_{31}=35%)	(1) Organization of graduate sports activities and sports events. (2) Graduate team construction, financial support and funding, and utilization of sports facilities or venues. (3) Awards for graduate student sports activities.
	Organization and Implementation of Aesthetic Education Activities P_{32} (W_{32}=30%)	(1) The organization of graduate student aesthetic education activities. (2) Graduate team construction, financial support and funding, and aesthetic education facilities or venue utilization. (3) Awards for graduate student aesthetic education creation.
	Organization and Implementation of Labor Education Activities P_{33} (W_{33}=35%)	(1) The organization of graduate labor education activities. (2) Graduate team building, financial support and funding, and the provision of graduate internship and training opportunities, vocational training, and services. (3) Awards for graduate labor practice.
Additional Indicators P_4	Additional score index P_{41}	(1) There is no weight for the additional score index. (2) If the training unit makes exceptional contributions or outstanding achievements in a certain level index, 0.5-2 points can be added for each item. (3) This item's maximum limit of additional points is 10 points.
	Point Deduction index P_{42}	(1) There is no weight for the point deduction index. (2) If the training unit makes severe mistakes in a certain level index that have adverse effects, 1-3 points will be deducted for each item. (3) The current annual evaluation is unqualified if severe mistakes cause serious adverse effects.

Secondly, universities should focus on the balanced development of graduate students' comprehensive qualities. When setting the weighting of evaluation indicators, consideration should be given to the classification requirements for graduate student education, in order to avoid excessive emphasis on research capabilities while neglecting the cultivation of practical abilities and non-intellectual aspects. The evaluation indicator system should strengthen ethics and labor education assessment, guiding graduate students to establish correct values and a sense of labor. Graduate students in Materials and Chemical Engineering need not only solid theoretical knowledge and foundational

abilities but also practical skills and an innovative spirit. The evaluation system should thoroughly consider this and encourage graduate students to actively participate in practical projects and scientific and technological innovation activities.

Thirdly, establishing the evaluation system needs to be aligned with industry demands, and it is crucial to involve industry experts in constructing the evaluation system and evaluation process. Through methods such as expert review and the Analytic Hierarchy Process, the importance and weighting of evaluation indicators can be scientifically assessed, ensuring the scientific and practical nature of the evaluation. In addition, using project evaluation, practical assessment, oral presentations, peer evaluation, and student self-evaluation can increase the objectivity and accuracy of the evaluation results.

Lastly, the evaluation process may involve some difficult-to-quantify assessment indicators. Descriptive methods such as critical incidents, horizontal comparisons, and comprehensive interviews are commonly used to address this issue. For example, when evaluating the moral qualities of postgraduate students, instead of quantitatively assessing the inner spiritual dimension of the character of postgraduate students and using specific scores to measure a person's intrinsic moral standard, postgraduate students can be given moral requirements so that they can understand which behaviors do not conform to student codes of conduct.

In addition, universities can set up characteristic evaluation databases and information platforms, explore and analyze evaluation data, visualize evaluation results, and improve the comparability and guidance of evaluation results. This can help postgraduates better understand their strengths and weaknesses, guide their future learning and career development, and provide schools and teachers with a scientific and reasonable basis for decision-making. Ultimately, this will ensure that the evaluation results genuinely serve as a guiding tool for talent cultivation.

4. Conclusions

This paper investigates the construction of a competency-based comprehensive evaluation system for materials and chemical engineering graduate students. The study considers both the personal development of students and the management of academic institutions, confirming the efforts of graduate students in moral, intellectual, physical, aesthetic, and labor aspects. The evaluation methods are diverse and personalized, taking into account the effectiveness of graduate student training and the orientation of their personal development. Literature research and interview studies indicate that the evaluation goals are consistent with the educational concepts advocated by the state, facilitating the integration of comprehensive education and competency development. The thorough evaluation system for Materials and Chemical Engineering graduate students covers various factors such as evaluation objectives, indicators, and methods. It is supported by scientifically set and dynamically adjusted evaluation indicators, emphasizing the cultivation of practical skills and innovative spirit, strengthening ethics education and labor education, and improving the comparability and guidance of evaluation results. Due to the limitations of objective conditions, the accuracy optimization of evaluation indicators, weight allocation between different disciplines, and the promotion of graduate student classification development through evaluation require further exploration and research by the project team in the next stage.

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