Comparison on Major Courses Setting for Graduates of Mechanical Engineering in Domestic-foreign Universities

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Abstract. Mechanical engineering is one of the important basic disciplines and has significant position in national economy and social development, and then the high-level personal training is a critical target of the graduate education on mechanical engineering. The major course setting has great influence on the quality of graduates training. The grey relational analysis (GRA) is used to evaluate and compare the major course setting for graduates on mechanical engineering of some famous domestic-foreign universities qualitatively. After that, some suggestions on the major course setting for graduates on mechanical engineering are presented, which will have positive effect on the graduates training in mechanical engineering for domestic universities.

Keywords: Mechanical engineering; major course setting; domestic-foreign universities; qualitative evaluation; grey relational analysis.

1. Introduction

The "Outline of the National Medium and Long-Term Education Reform and Development Plan (2010-2020)" points out the importance of curriculum system construction in improving the quality of talent cultivation in universities in the "Improving the Quality of Talent Cultivation" section. The construction of the graduate curriculum system is directly related to the formulation of graduate training plans, the achievement of training objectives, and the reform of training models. It is an important component of the graduate training process and plays an important role in consolidating the theoretical foundation of graduate disciplines, strengthening professional knowledge, and cultivating theoretical thinking, innovation, and practical abilities.

The construction of graduate curriculum system is an important link in the cultivation of high-level talents in higher education institutions. How to conduct scientific, objective, and standardized quantitative evaluation is a key issue that needs to be solved in the construction of curriculum system. Course evaluation is the process of professional institutions and personnel selecting appropriate methods for qualitative or quantitative analysis, judgment, and decision-making of courses based on certain criteria, specific purposes, and relevant procedures, and proposing relevant opinions and suggestions. As a basic link and an important part of educational assessment, curriculum evaluation is not only an important means of supervision and regulation of colleges and universities, but also an effective way for colleges and universities to improve, adjust and improve themselves [2]. Given that most current curriculum system evaluations are based on the average sum of expert knowledge, researching a more scientific, reasonable, and effective curriculum evaluation method is an important guarantee for improving teaching quality and deepening teaching reform. Literature [3,4] used the grey correlation analysis method to comprehensively evaluate software performance and knowledge management level, and to a greater extent, explored the internal correlation and mutual influence of potential factors on relevant variables. Therefore, this article explores the application of grey correlation analysis method to curriculum evaluation and analysis, in order to objectively study the correlation between explicit indicators and internal factors of the curriculum system, more accurate and reliable evaluation results are obtained.

From the perspective of discipline development in the 21st century, the fundamental role of mechanical engineering in national economic and social development has never changed, and it is also one of the basic components of Intersectionality disciplines such as military intelligence science. This article quantitatively evaluates and compares the various settings and basic characteristics of the curriculum system construction of mechanical engineering graduate students in domestic and foreign universities through the grey correlation analysis method. It provides corresponding inspiration and suggestions for the construction of the curriculum system of mechanical engineering graduate students in domestic universities, which has important reference significance for improving the training level of mechanical engineering graduate students in domestic universities.

2. Curriculum design and evaluation indicators

Mechanical engineering is a fundamental engineering discipline commonly offered in universities both domestically and internationally. Therefore, this article analyzes and evaluates the curriculum system of mechanical engineering graduate programs in representative universities both domestically and internationally. Foreign universities choose the University of Albert (UA) in Canada and the University of Manchester(UM) in Britain as samples, while the domestic universities choose Xi'an Jiaotong University(XJU) and Tsinghua University(TU) as samples for analysis.

2.1 Curriculum System

University of Albert is one of the top 5 famous universities in Canada, with the first-class mechanical engineering discipline in North America, while the mechanical engineering discipline of the University of Manchester enjoys a high reputation in the UK and even the world. From the world ranking of disciplines, it can be seen that the development level of mechanical engineering disciplines in these two schools is on the same level as the mechanical engineering disciplines in top domestic universities. Therefore, these two universities were selected as control samples for foreign universities. The postgraduate professional courses and related research directions of Albert University and University of Manchester are shown in Table 1.

Table 1. Curriculum and Research Direction Setting for Mechanical Engineering Graduate Students in Foreign Universities

Institution	Theoretical courses	Applied courses	Developmental courses	Extensionality courses	Research direction
University of Alberta	1. Fluid mechanics 2. Eddy current mechanics 3. Environmental fluid mechanics 4. Nanomechanics 5. Continuum mechanics 6. Micro fracture mechanics 7. Linear elasticity	1. Renewable energy engineering and sustainability 2. Particle engineering 3. Theory and application of finite element method 4. Aerosol science and technology 5. Advanced design and simulation methods for micro nano electromechanical sensors 6. Introduction to polymer	1. Computer aided product modeling and manufacturing engineering 2. Engineering economics analysis 3. Design and integration of standardized systems 4. Optimization methods for large-scale linearization problems	1. Introduction to intellectual property and commercialization of new technologies 2. Quality confirmation and evaluation system	1. Energy and Environment 2. Engineering management 3. Micro nano technology 4. Heat flow research 5. Solid mechanics 6.

		micromanufacturing 7. Application of statistical mechanics 8. Experimental design in mechanical engineering 9. Fundamentals of engineering numerical analysis 10. Heat conduction engineering			Biomechanical and biomedical engineering
University of Manchester	1. Introduction to structural integrity 2. Advanced vibration theory 3. Maintenance system theory	1. Finite element method 2. Reliability and maintainability engineering 3. Composite material engineering 4. Impact and explosives engineering 5. Condition based maintenance 6. Mechanical vibration monitoring and analysis 7. Maintenance design method	1. Engineering optimization methods 2. Research methods 3. Engineering design 4. Maintenance strategy 5. Reliability, maintainability, and risk analysis	1. Maintenance system audit 2. Full cycle management 3. Maintenance organization method	1. Mechanical engineering design 2. Maintenance engineering and asset management

The mechanical engineering discipline of Tsinghua University and Xi'an Jiaotong University and obtained A+ results in the fifth round of discipline evaluation by the Ministry of Education. Generally speaking, they are in the leading ranks of domestic mechanical engineering disciplines, representing the advanced level of mechanical engineering discipline in Chinese universities. Therefore, they are selected as samples of domestic universities for comparative analysis. The postgraduate professional courses and research directions of Xi'an Jiaotong University and Tsinghua University are shown in Table 2.

Table 2. Curriculum and Research Direction Setting for Mechanical Engineering Graduate Students in Domestic Universities

Institution	Theoretical courses	Applied courses	Developmental courses	Extensionality courses	Research direction
Xi'an Jiaotong University	1. Vibration theory 2. Modern theory of nonlinear dynamics 3. Fundamentals of reliability design 4. Strength of	1. Modern testing technology 2. Theoretical basis and application of CAD/CAM/CAE 3. Modern signal processing	1. Several methods in scientific research 2. Frontiers of mechanical design 3. Intelligent machinery	1. Natural fund application for simulation courses	1. Lubrication theory and bearing rotor dynamics 2. Mechanical fault diagnosis and prediction 3. High speed and precision

	materials 5. Optimal control 6. Mathematical Statistics 7. Stochastic process 8. Numerical heat transfer 9. Theory of elasticity 10. Plastic theory 11. Functional analysis and applications 12. Nonlinear analysis 13. Optimization theory and methods 14. Computational fluid dynamics	technology and applications 4. Modern control engineering 5. Finite element principles and engineering applications 6. Analysis and synthesis of robot mechanisms 7. Optimal control 8. Dynamic system modeling 9. Mechanical vibration engineering analysis theory and control technology	4. Advanced manufacturing and processing technology and equipment 5. Modern mechanical design		processing technology and equipment 4. Digital design and manufacturing 5. Micro/Nano manufacturing and MEMS 6. Biological manufacturing and testing 7. Advanced forming technology and equipment 8. Electromechanical control and hydraulic transmission
Tsinghua University	1. Fundamentals of control theory 2. Computer control of mechanical systems 3. Finite element analysis 4. Principles and applications of electromechanical system control 5. Modern material processing 6. Modern material analysis technology 7. Mechanical CAD/CAM 8. Fundamentals of testing and inspection technology 9. Material wear resistance and surface engineering	1. Digital simulation of mechanical systems 2. Material processing simulation technology	1. Computer numerical analysis 2. Frontiers of engineering disciplines	1. Engineering management 2. Production and operation management 3. Literature review and topic selection course	1. Digital design and analysis 2. Basic theory and technology of tribology 3. Micro/Nano mechanics and tribology 4. Surface interface theory and technology 5. Mechanical components and sealing technology 6. Mechanical system dynamics and fault diagnosis technology 7. Biomechanical systems and rehabilitation engineering 8. Advanced manufacturing equipment and controls

In this study, in order to facilitate the analysis and evaluation of the curriculum system, all courses are divided into four categories: theoretical courses, applied courses, developmental courses and Extensionality courses. Among them, the ideological and political elements of the development curriculum and the extensionality curriculum are more abundant, and they are one of the main carriers of ideological and political education of mechanical engineering courses.

2.2 Evaluation Indicators

Before quantitatively evaluating the curriculum system of mechanical engineering graduate programs in domestic and foreign universities, it is necessary to first set up relevant evaluation indicators and conduct quantitative analysis on them. The indicator system is the basis and scale for objectively judging the current situation of the curriculum system, and it can also play a guiding role in the development and reform of the curriculum system. Setting appropriate curriculum evaluation indicators is a prerequisite for correctly evaluating the curriculum system. In this study, we set up directional indicators, novelty indicators, intersectionality indicators, extensionality indicators, theoretical indicators and application indicators to systematically and comprehensively evaluate the curriculum system of each university. Directional indicators are used to evaluate the supporting role of postgraduate curriculum system on research direction, novelty indicators are used to measure the proportion of new theories, new methods and new technology related content in the curriculum system, intersectionality indicators are used to judge the level of communication and integration between mechanical engineering discipline and other disciplines, and extensionality indicators are used to describe the expansion of the curriculum system to other fields, theoretical indicators are used to indicate the proportion of theoretical courses in the curriculum system, while applied indicators are used to indicate the proportion of applied courses in the curriculum system. In this paper, the quantification methods and weights of various indicators in the curriculum system of mechanical engineering graduate students in domestic and foreign universities are shown in Table 3.

Table 3. Index and Grading of the Curriculum System for Mechanical Engineering Graduate Students in Chinese and Foreign Universities

	Directional indicators	Novelty indicators	Intersectionality indicators	Extensionality indicators	Theoretical indicators	Application indicators
Calculation method	Number of research directions/Total number of courses	Number of innovative courses/Total number of courses	Number of courses combined with other disciplines/Total number of courses	Number of courses/Total number of courses for non-engineering majors	Number of theoretical courses/Total number of courses	Number of applied courses/Total number of courses
Standard value of indicator	0.2	0.5	0.9	0.2	0.3	0.5
Weight of indicator	0.2	0.2	0.2	0.2	0.1	0.1
UA	6/23	7/23	21/23	2/23	7/23	10/23
UM	2/18	4/18	15/18	3/18	3/18	7/18
XJU	8/29	3/29	21/29	1/29	14/29	9/29
TU	8/16	8/16	13/16	3/16	9/16	2/16

3. Curriculum System Evaluation Model

The course evaluation system can be seen as a complex grey system, evaluated and analyzed through an indicator system. Grey correlation analysis is an important component of grey system theory, mainly used for quantitative analysis of systematic statistical differences between two or more types of samples. Based on the characteristics of grey correlation analysis, it can be applied to quantitative evaluation and comparison of curriculum systems.

When evaluating the curriculum system using traditional methods, non-quantitative evaluation indicators such as "excellent, good, medium, poor" or "up to standard, not up to standard" are often involved. This method needs to first convert these indicators into quantitative indicators. Assuming that after quantitative processing, the indicator vector of a certain course system $\mathbf{Y}_j$ obtained is

$$\mathbf{Y}_j = (y_{ji}) = \{y_{j1}, y_{j2}, \dots, y_{jn}\} \tag{1}$$

where, there are n indicators in the curriculum system, y_{ji} is the ith indicator.

Each indicator of the curriculum system is set with an optimal value, and the optimal value of each indicator is formed into a vector, which is the standard vector $\mathbf{Y}_0$, which is used as a benchmark to measure the different curriculum systems of various universities,

$$\mathbf{Y}_0 = (y_{0i}) = \{y_{01}, y_{02}, \dots, y_{0n}\} \tag{2}$$

where y_{0i} is the standard value of the indicator y_{ji}. Due to the varying degrees of impact of each evaluation indicator on the curriculum system, it is necessary to distinguish the role of each indicator in the model. Therefore, we set the weight vector **W** of the indicator system as

$$\mathbf{W} = (w_i)_n = \{w_1, w_2, \dots, w_n\} \tag{3}$$

where w_i is the weight of indicator y_{ji}.

Then, the correlation degree vector $\boldsymbol{\eta}_j$ between the indicator vector $\mathbf{Y}_j$ and the standard vector $\mathbf{Y}_0$ is calculated as follows,

$$\boldsymbol{\eta}_j = (\eta_{ji})_n = \left\{ \frac{\min\limits_{i=1,2,..n}\{A_i\} + \beta \max\limits_{i=1,2,..n}\{A_i\}}{A_i + \beta \max\limits_{i=1,2,..n}\{A_i\}} \right\} \tag{4}$$

where $A_i = \left| w_i \left(y_{ji} - y_{0i} \right) \right|$, β is the distinguishing coefficient, the function of β is to balance the differences between indicators, and to weaken the distortion caused by the maximum absolute difference value being too large, and to reduce the impact of extreme values on the final result. In this paper the value of β is 0.5.

In the evaluation model of this paper, the average value E_j of the correlation degree vector $\boldsymbol{\eta}_j$ of the indicator vector $\mathbf{Y}_j$ is used as the final evaluation result of the course system,

$$E_j = \frac{1}{n} \sum_{i=1}^{n} \eta_{ji} \tag{5}$$

It should noted that, the smaller the evaluation result obtained in Equation (5), the better the evaluation object is under the given indicator system.In order to obtain more intuitive and consistent evaluation results with analytical habits, E_j is further converted into

$$\hat{E}_j = \left(1 - E_j\right) \times 100 \tag{4}$$

where the unit of $\hat{E}_j$ is percentage (%).

When qualitative or categorical descriptions of evaluation objects are needed, classification could be based on the interval where the final quantitative evaluation results are located. For example, when $\hat{E}_j$ <10, the evaluation result type is D; when the level of $\hat{E}_j$ is within the range of [10, 20), the evaluation result level is C; when the value of $\hat{E}_j$ is within the range of [20, 30), the evaluation result level is B; when $\hat{E}_j \geq$ 30, the evaluation result level is A.

4. Quantitative Curriculum System Evaluation

The standard vector $\mathbf{Y}_0$ used in quantitative curriculum system evaluation could be obtained from Table 3, which is $[0.2,0.5,0.9,0.2,0.3,0.5]$, the weight vector is $[0.2,0.2,0.2,0.2,0.1,0.1]$. The indicator vectors of UA, UM, XJU and TU are $[\frac{6}{23},\frac{7}{23},\frac{21}{23},\frac{2}{23},\frac{7}{23},\frac{10}{23}]$, $[\frac{2}{18},\frac{4}{18},\frac{15}{18},\frac{3}{18},\frac{3}{18},\frac{7}{18}]$, $[\frac{8}{29},\frac{3}{29},\frac{21}{29},\frac{1}{29},\frac{14}{29},\frac{9}{29}]$ and $[\frac{8}{16},\frac{8}{16},\frac{13}{16},\frac{3}{16},\frac{9}{16},\frac{2}{16}]$.

The indicator vectors above are substituted in the algorithm of GRA, and then the evaluation results of mechanical engineering curriculum system of the four universities are listed in Table 4.

Table 4. Evaluation results of mechanical engineering curriculum system

	UA	UM	XJU	TU
Score of result	31.83	19.42	28.50	31.44
Level of result	A	C	B	A

From the evaluation results, it can be seen that under the indicator system set in this paper, the mechanical engineering graduate course system of the UA has the highest score, while the UM has a relatively low score. In terms of setting up the professional curriculum system for graduate students of mechanical engineering discipline, UA and TU are similar in level, the evaluation levels of the two universities are A, and XJU have high score which is close to UA and TU, the evaluation level is B, and UM has a level of C. By analyzing and comparing the above evaluation results, the conclusions are listed as follows:

(1) The research directions of mechanical engineering discipline in foreign universities are few, while the characteristics of relevant research directions in domestic universities are often many and comprehensive. For example, mechanical engineering in the UA has six research directions, while the relevant disciplines in the UM have only two research directions, while XJU and TU in China have eight main research directions;

(2) Domestic universities pay more attention to theoretical courses, with a large proportion of theoretical courses, while foreign universities pay more attention to applied courses and Extensionality courses, and pay more attention to the cultivation of students' professional ability and overall ability;

(3) The curriculum system of foreign universities is closely related to the main research directions and regional industrial development, and limited to the local industrial system, it is difficult to establish multiple disciplinary directions; Based on the integrity of the domestic industry chain, high-level universities in China are more likely to develop a relatively complete research direction and curriculum system for their curriculum system.

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5. Summary

A course system evaluation method based on grey correlation analysis are proposed in this paper, and the indicator system is presented for the course system evaluation of mechanical engineering. Based on this, a quantitative evaluation and comparative analysis of the mechanical engineering graduate course system in Chinese and foreign universities were conducted. The analysis conclusion is of great significance for deepening the reform of the curriculum system, improving teaching effectiveness and quality, and forming a self-restraint and regulatory mechanism for the healthy development of the curriculum system. The evaluation method of this course system can be applied to the quantitative evaluation of other types of course systems and teaching levels.

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