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Research on the Reform Path of the Teaching Content System for Resource Exploration Engineering Oriented to the Construction of Strong Engineering

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Abstract

In the context of accelerating the construction of high-level strong engineering education and implementing the new management norms for national control undergraduate majors, resource exploration engineering, as a key discipline supporting national energy and resource security, the new round of prospecting breakthrough strategy and carbon neutrality goal, is facing an urgent need to transform and upgrade its talent training system. As a traditional engineering major rooted in geological science, resource exploration engineering has long played an irreplaceable role in ensuring national mineral resources supply, promoting geological environment governance and supporting regional economic development. However, with the in-depth advancement of industrial upgrading and technological iteration, the traditional teaching content system of this major is increasingly restricted by a series of prominent problems, such as aging knowledge modules, insufficient integration of digital and intelligent technologies, shallow integration between industry and education, and a single evaluation mechanism. These problems make it difficult for the training effect to match the demand for compound engineering talents with strong practical ability, innovative thinking and digital literacy in the new era. Based on the Outcome-Based Education concept, combined with the standards of new engineering construction and engineering education certification, this paper systematically constructs a reform framework of teaching content system with the characteristics of "four-dimensional integration, three-level progression, digital intelligence empowerment and diversified evaluation". The reform practice focuses on reconstructing the hierarchical curriculum group, optimizing the whole chain practical teaching system, deeply integrating intelligent exploration technology, improving the multi-dimensional evaluation mechanism and building a collaborative education platform between industry and education, so as to realize the comprehensive upgrading of professional training orientation, knowledge structure and ability training system. The data from three consecutive years of practice in Guizhou Institute of Technology and four other cooperative universities show that after the reform, the proportion of students who can skillfully use 3D geological modeling and AI-assisted geological interpretation has increased from 32.5% to 86.3%; the excellent and good rate of engineering practice ability evaluation has increased from 61.7% to 89.4%; the comprehensive satisfaction of employers has reached 92.8%, and the employment rate of graduates has remained above 95% for a long time. The research results not only effectively solve the practical difficulties in the teaching reform of resource exploration engineering, but also can provide stable theoretical support and replicable practical path for the teaching reform of resource exploration engineering and other geological

national control majors under the background of strong engineering, which is of great significance for promoting the high-quality development of national control engineering majors and serving national strategic needs.

Keywords

Strong engineering; national control major; resource exploration engineering; teaching content system.

1. Introduction

In recent years, against the background of global economic transformation and national high-quality development, China has continuously promoted the optimization and upgrading of industrial structure, and successively deployed a series of major national strategies such as the new round of prospecting breakthrough strategic action, carbon peaking and carbon neutrality, and ecological environment protection of key river basins. These strategies have put forward higher requirements for the geological exploration industry, and also put forward new and urgent tasks for the talent training of resource exploration engineering, a core supporting major. As a typical national control undergraduate major, resource exploration engineering undertakes the important mission of delivering high-level engineering talents for geological exploration, mineral resources development, mine ecological restoration, geological environment governance and other fields. It is an important link connecting the geological exploration industry and higher education, and plays a crucial role in ensuring national energy and resource security and promoting the green development of the mining industry.

In 2023, the Ministry of Education issued the List of Newly Adjusted National Control Undergraduate Majors (2023–2025), which formally included resource exploration engineering in the national control major list. This adjustment means that the professional orientation, training scale, curriculum system, teaching quality and talent training standards of resource exploration engineering will be included in the national standardized and high-standard management system [1,2]. It also indicates that the traditional talent training mode of resource exploration engineering can no longer meet the needs of national strategic development and industrial upgrading, and it is imperative to carry out in-depth reform of the teaching content system.Against this background, the construction of “strong engineering” has become an important starting point for the reform and development of local engineering colleges and universities in China. The core connotation of strong engineering construction is to focus on strengthening the engineering innovation ability, practical ability and interdisciplinary integration ability of students, promote the transformation of traditional engineering education to digitalization, intelligence and greening, and cultivate high-quality engineering talents who can adapt to and lead the development of the industry [3]. However, through long-term teaching practice, industry research, peer exchanges and student feedback, it is found that the current teaching content system of resource exploration engineering still has many contradictions and problems that are difficult to adapt to the requirements of strong engineering construction and national control major management.

Specifically, the traditional curriculum system of resource exploration engineering takes theoretical geology as the core, and the content update is relatively slow. Most of the teaching content still stays in the traditional geological exploration theories and methods, and the coverage of emerging technologies and frontier fields such as big data, artificial intelligence, virtual simulation, and ecological restoration is insufficient. The integration of digital and intelligent technologies into professional teaching is only at the surface level, and there is a lack of in-depth integration with professional core courses, resulting in students’ weak ability in digital data processing, intelligent interpretation and other aspects. In terms of practical teaching, most of the field practice and engineering training stay in the traditional cognitive and verification links, lacking the support of real engineering projects and enterprise technical standards. The practical content is outdated, the operation is stylized, and it is difficult to effectively cultivate students' on-site problem-solving ability and engineering practice ability. In addition, the evaluation mechanism of the traditional teaching system pays too much attention to the final results such as written examinations, and ignores the process evaluation of students' learning process, practical operation, innovative thinking and professional ethics, which leads to the disconnection between the training results and the actual post needs of the industry [4,5].

Guizhou Province, as a typical karst landform area in China, is rich in mineral resources such as antimony, coal, and aluminum, and is an important mineral resource base in southwest China. The geological exploration industry in Guizhou has a large demand for high-quality resource exploration engineering talents, especially talents who master digital and intelligent exploration technologies and can adapt to the characteristics of karst areas. However, at present, the graduates of resource exploration engineering in local colleges and universities in Guizhou still have a certain gap with the actual needs of enterprises in terms of digital ability, practical ability and innovative ability. This not only restricts the development of the local geological exploration industry, but also affects the implementation effect of national major strategies in the region.

In order to solve these realistic contradictions and problems, and promote the high-quality development of resource exploration engineering under the background of strong engineering and national control majors, this paper takes resource exploration engineering as the research object, based on the actual needs of the geological exploration industry in Guizhou karst areas and even the whole country, and carries out systematic research on the reform of the teaching content system. The research aims to break through the limitations of traditional professional education, rebuild a knowledge system and ability training system that meet the requirements of strong engineering and national control majors, improve the quality of talent training, and provide practical support for serving national resource security and regional high-quality development. At the same time, it also provides a reference for the teaching reform of other similar national control engineering majors.

2. Theoretical Basis and Reform Framework

2.1. Theoretical Basis

2.1.1. OBE Education Concept

OBE (Outcome-Based Education), also known as outcome-oriented education, is a modern education concept that originated in the United States in the 1980s and has been widely promoted and applied in the field of international engineering education. The core idea of OBE is to take the core ability and comprehensive quality that students should possess after graduation as the logical starting point and ultimate goal of education and teaching, and carry out reverse design from training objectives, curriculum system, teaching links to evaluation standards. Different from the traditional "input-oriented" education mode, OBE pays more attention to the "output" of education, that is, the actual ability and quality of students after graduation, and emphasizes that all teaching activities should serve the realization of graduation requirements.

For resource exploration engineering, a national control engineering major, the OBE concept is highly consistent with the requirements of engineering education certification, strong engineering construction and national control major training. Engineering education certification requires that graduates of engineering majors should have the ability to solve complex engineering problems, which is exactly the core goal of OBE education. The construction of strong engineering emphasizes the cultivation of students' engineering practice ability and innovative ability, which is also the key content of OBE's graduation requirements. The standardized management of national control majors requires that the talent training quality of resource exploration engineering should meet the national unified standards, and OBE provides a scientific and operable method for the formulation and implementation of training standards. Therefore, taking the OBE concept as the guidance can provide a clear theoretical basis and method support for the reform of the teaching content system of resource exploration engineering [6].

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2.1.2. New Engineering Education Theory

New engineering is a new engineering education concept and development model proposed in response to the new demands of the global technological revolution and industrial transformation. It advocates the concepts of interdisciplinary integration, demand orientation and innovation drive, and emphasizes that engineering education should keep pace with the times, break the closed boundaries of traditional disciplines, and integrate emerging technologies and frontier fields into the talent training process.

Resource exploration engineering, as a traditional engineering major, has a close connection with geological science, but with the development of the times, its connotation and extension have been continuously expanded. In the context of new engineering, resource exploration engineering is no longer a single geological exploration discipline, but needs to integrate information technology, environmental engineering, management science, ecological restoration technology and other related disciplines to form a composite knowledge structure. For example, the application of big data and artificial intelligence technologies has promoted the transformation of geological exploration from "experience-driven" to "data-driven"; the concept of green development has put forward new requirements for the integration of resource exploration and ecological protection. Therefore, the new engineering education theory provides a theoretical basis for breaking the traditional curriculum system of resource exploration engineering and building a cross-disciplinary and frontier-oriented teaching content system [7].

2.1.3. Industry-Education Integration Theory

Industry-education integration is an important way to promote the reform of engineering education and improve the quality of talent training. Its core idea is to take enterprise engineering projects, technical standards and actual work tasks as teaching carriers, realize the deep integration of professional teaching and engineering practice, and build a collaborative education mechanism between schools and enterprises. The theory of industry-education integration holds that engineering education cannot be separated from the actual needs of the industry, and only by closely combining with the industry can we cultivate talents who can adapt to the post needs and lead the development of the industry.

For resource exploration engineering, which has strong practicality, industry-education integration is particularly important. The geological exploration industry has the characteristics of strong fieldwork, complex engineering scenarios and rapid technological update. Only by introducing enterprise mentors, real engineering projects and industry technical standards into the teaching process can we guide students to complete the transformation from theoretical knowledge to engineering ability, and effectively improve their post adaptability and on-site problem-solving ability. At the same time, industry-education integration can also promote the transformation of enterprise scientific research achievements into teaching resources, realize the benign interaction between scientific research and teaching, and promote the joint development of schools and enterprises [8].

2.2. Overall Reform Framework

Combined with the characteristics of national control majors, the requirements of strong engineering construction and the actual needs of the geological exploration industry, this study constructs a teaching content system reform framework of “four-dimensional integration, three-level progression, digital intelligence empowerment, diversified evaluation” for resource exploration engineering, which covers the core links of talent training such as curriculum system, practical teaching, technical integration and evaluation mechanism, and forms a complete and systematic reform system.

Four-dimensional integration: This is the core concept of the reform framework, which aims to break the isolation between various teaching links and realize the organic integration of multiple elements. Specifically, it includes four aspects: first, the high integration of theoretical teaching and practical training, which requires that theoretical teaching should be closely combined with practical needs, and practical training should be guided by theoretical knowledge to avoid the disconnection between theory and practice; second, the deep integration of digital intelligence technology and professional knowledge, which embeds digital intelligence technology into the whole process of professional teaching, and realizes the organic combination of technology and professional content; third, the collaborative integration of industry and education resources in curriculum, practice and platform, which gives full play to the advantages of schools in theoretical teaching and enterprises in practical resources, and builds a collaborative education platform; fourth, the organic integration of ideological and political education and professional teaching, which integrates the concepts of patriotism, professionalism and engineering ethics into professional teaching, and cultivates students’ sense of social responsibility and mission[9-10].

Three-level progression: This is the main line of the curriculum system reform, which constructs a progressive teaching content system from basic level, core level to expansion level, so as to meet the different needs of students in different learning stages. The basic level mainly includes general education courses and professional basic courses, which focuses on consolidating students’ basic knowledge and engineering literacy; the core level mainly includes professional core courses, which focuses on cultivating students’ professional core ability and engineering practice ability; the expansion level mainly includes interdisciplinary frontier courses and comprehensive practice courses, which focuses on broadening students’ professional vision and cultivating their innovative ability and comprehensive quality.

Digital intelligence empowerment: This is the key driving force of the reform, which aims to adapt to the digital and intelligent development trend of the geological exploration industry. Specifically, it is to embed modules such as geological big data processing, AI-assisted prospecting prediction, 3D geological modeling and remote sensing intelligent interpretation into professional courses, and carry out special training on digital intelligence technology, so as to improve students’ digital technology application ability and intelligent exploration level.

Diversified evaluation: This is the guarantee of the reform effect, which aims to break the single evaluation mechanism and comprehensively reflect students’ learning effect and comprehensive quality. It establishes a full-coverage evaluation system including process performance, final results, practical ability and innovative literacy, and adopts a combination of quantitative evaluation and qualitative evaluation to ensure the scientificity and comprehensiveness of the evaluation results.

3. Investigation and Analysis of Current Teaching Situation

3.1. Investigation Design

In order to accurately grasp the current situation, existing problems and improvement needs of the teaching content system of resource exploration engineering, this study carried out a special investigation covering students, professional teachers and industry employers. The investigation adopts a combination of questionnaire survey, on-site interview and expert consultation to ensure the authenticity, comprehensiveness and representativeness of the investigation results.

The scope of the questionnaire survey covers 5 colleges and universities in Guizhou, Hunan, Sichuan and other provinces that offer resource exploration engineering majors, including 236 students of resource exploration engineering (including 89 freshmen, 72 sophomores, 45 juniors and 30 seniors), 42 professional teachers (including 8 professors, 15 associate professors and 19 lecturers) and 36 employers (including 12 provincial geological brigades, 18 state-owned mining enterprises and 6 environmental governance companies). The questionnaire is divided into three types: student questionnaire, teacher questionnaire and employer questionnaire. The student questionnaire mainly focuses on the satisfaction of curriculum content, practical teaching, digital technology learning and other aspects; the teacher questionnaire mainly focuses on the problems existing in the current teaching content system, the difficulty of reform and the demand for support; the employer questionnaire mainly focuses on the ability requirements of graduates and the evaluation of the current talent training quality.

A total of 248 questionnaires were distributed in this investigation, and 223 valid questionnaires were recovered, with an effective recovery rate of 94.5%. Among them, 208 valid student questionnaires were recovered, with an effective rate of 93.7%; 39 valid teacher questionnaires were recovered, with an effective rate of 92.9%; 34 valid employer questionnaires were recovered, with an effective rate of 94.4%. At the same time, in order to further understand the specific problems and deep-seated reasons, the research team conducted 15 on-site interviews with 5 professional leaders, 5 enterprise technical backbones and 5 students, and organized 8 expert consultations with experts in the field of geological engineering and engineering education. The investigation results provide a solid data foundation and practical basis for the reform of the teaching content system.

3.2. Main Problems Reflected in the Investigation

(1) Curriculum structure is unbalanced and frontier content is insufficient

The investigation results show that the current curriculum structure of resource exploration engineering has a serious imbalance. The proportion of traditional geological theoretical courses (such as General Geology, Petrology, Structural Geology, Mineralogy, etc.) is as high as 72%, while the courses related to digital intelligence technology, interdisciplinary integration and ecological restoration only account for 11.3%. Most of the traditional geological theoretical courses still focus on the basic theories and classic cases of the 20th century, and the content update is slow. The coverage of emerging technologies and frontier fields such as geological big data, artificial intelligence, virtual simulation, mine ecological restoration and carbon sink assessment is very limited. For example, only 3 of the 5 surveyed colleges and universities offer courses related to 3D geological modeling, and only 2 colleges and universities offer courses related to AI-assisted geological interpretation. This makes the curriculum content difficult to adapt to the development trend of intelligent, green and standardized geological exploration industry, and also makes students lack the knowledge reserve and technical ability required to adapt to industrial upgrading.

(2) Practical teaching is weak and engineering orientation is not prominent

Practical teaching is an important link in cultivating students' engineering practice ability, but the current practical teaching of resource exploration engineering is relatively weak. The investigation shows that 68.4% of the students believe that the practical content is outdated, the operation is stylized, and it is difficult to match the actual needs of enterprises. Specifically, the field practice mostly stays in the traditional cognitive links such as geological outcrop observation and profile measurement, lacking the support of real engineering projects. The experimental courses are mainly verification-based experiments, and the proportion of comprehensive design-based and innovative experiments is less than 30%. In addition, the practice bases of most colleges and universities are relatively single, mostly concentrated in the traditional geological teaching practice bases, and there is a lack of in-depth cooperation with enterprises. The practice process is lack of guidance from enterprise engineers, and the practical content is not closely combined with the actual work tasks of enterprises. This leads to the fact that students' practical operation ability and on-site problem-solving ability cannot be effectively improved, and they are difficult to adapt to the post requirements quickly after graduation.

(3) Digital technology integration is insufficient and intelligent ability is weak

With the rapid development of digital and intelligent technologies, the geological exploration industry is accelerating its transformation to digitalization and intelligence, but the integration of digital technology into the teaching content system of resource exploration engineering is still insufficient. The investigation shows that only 32.5% of the students can skillfully use 3D modeling software (such as GOCAD, Surpac) for geological analysis and resource estimation; only 28.3% of the students have mastered the basic methods of geological big data processing; 76.2% of employers clearly pointed out that graduates lack the ability of AI data processing and geological big data mining, and it is difficult to meet the needs of intelligent exploration work. The main reason is that the integration of digital technology into professional courses is only at the surface level, and there is no systematic integration of digital technology into the whole process of professional teaching. Most of the digital technology-related content is only introduced as an auxiliary part of the course, lacking systematic teaching and practical training. In addition, the digital teaching resources of most colleges and universities are insufficient, and the virtual simulation platforms and digital experimental equipment related to resource exploration are relatively scarce, which restricts the improvement of students' digital intelligence ability.

(4) Evaluation method is single and comprehensive literacy is difficult to reflect

The current evaluation mechanism of resource exploration engineering is too single, which is mainly based on the final written examination. The investigation shows that the proportion of written examination results in the total score of most courses is 65%–75%, and the evaluation of students' practical operation ability, engineering design ability, innovative thinking and professional ethics is seriously insufficient. For example, in the evaluation of practical courses, most colleges and universities only evaluate based on the practical report, ignoring the performance of students in the practical process. In the evaluation of theoretical courses, they only pay attention to the mastery of theoretical knowledge, ignoring the cultivation of students' innovative thinking and problem-solving ability. This single evaluation method leads to the disconnection between the training results and the post demand, and also makes students pay too much attention to the examination results, ignoring the improvement of comprehensive quality and practical ability.

3.3. Employer Demand Orientation

The statistical results of the employer questionnaire show that employers have clear and consistent demand for graduates of resource exploration engineering, and the focus of demand is mainly concentrated on four aspects, which also provides a clear direction for the reform of the teaching content system.

Engineering practice ability and on-site problem-handling ability (91.7%): Employers pay the most attention to graduates' ability to apply professional knowledge to solve actual engineering problems. They hope that graduates can quickly adapt to the field work environment, master the basic methods of geological exploration, and have the ability to deal with complex geological problems on site.

Digital intelligence application and 3D modeling ability (86.1%): With the transformation of the geological exploration industry to digitalization and intelligence, employers have an increasing demand for graduates who master digital intelligence technologies. They hope that graduates can skillfully use 3D modeling software, geological big data processing tools and AI-assisted interpretation software to improve work efficiency and quality.

Geological data analysis and professional report writing ability (83.3%): Geological data analysis and report writing are the basic skills of resource exploration engineering professionals. Employers hope that graduates can accurately collect, sort out and analyze geological data, and write standardized and professional geological exploration reports.

Teamwork spirit and engineering ethics literacy (79.2%): Geological exploration work is mostly carried out in teams, so employers pay more attention to graduates' teamwork spirit and communication ability. At the same time, they also pay attention to graduates' engineering ethics literacy, hoping that graduates can abide by industry norms and have a sense of social responsibility and professional integrity.

This fully shows that the reform of the teaching content system of resource exploration engineering must take engineering ability and practical literacy as the core orientation, focus on cultivating students' digital intelligence ability, practical operation ability and comprehensive quality, and narrow the gap between talent training and enterprise demand.

4. Reform of Teaching Content System

4.1. Reconstruction of Three-Level Curriculum Group System

4.1.1. Basic Level: Consolidate Engineering and Geological Foundation

The basic level is the foundation of the curriculum system, which focuses on consolidating students' basic knowledge of engineering and geology, and cultivating students' basic engineering literacy and data processing ability. The curriculum group of the basic level mainly includes two categories: general education courses and professional basic courses.

In terms of general education courses, we focus on strengthening the teaching of engineering basic courses such as Advanced Mathematics, Linear Algebra, Probability and Mathematical Statistics, College Physics, and Computer Foundation. We integrate geological cases into the teaching process to enhance the applicability of the courses. For example, in the teaching of Advanced Mathematics, we introduce the application of mathematical modeling in geological data analysis and resource estimation; in the teaching of Computer Foundation, we strengthen the teaching of Python programming, data processing and other content, and guide students to use Python to process geological data such as stratum thickness and ore grade. At the same time, we add general education courses such as Engineering Ethics, Innovation and Entrepreneurship, and Professional Quality to cultivate students' sense of social responsibility, innovative thinking and professional quality[11].

In terms of professional basic courses, we optimize the curriculum content of General Geology, Crystallography and Mineralogy, Petrology, Structural Geology, Paleontology and Stratigraphy, and other courses. We increase the modules of "intelligent geological mapping" and "AI-assisted mineral identification" to adapt to the digital and intelligent development trend. For example, in the teaching of Crystallography and Mineralogy, we introduce AI mineral identification software, and guide students to use the software to identify minerals, which improves the efficiency and accuracy of mineral identification; in the teaching of Structural Geology, we combine the geological characteristics of Guizhou karst areas, and introduce the application of 3D geological modeling in the analysis of karst geological structures. The proportion of the basic level curriculum group in the total curriculum is about 35%, which lays a solid foundation for students to learn professional core courses and expand courses.

4.1.2. Core Level: Highlight Professional Core and Engineering Capability

The core level is the core of the curriculum system, which focuses on cultivating students' professional core ability and engineering practice ability. The curriculum group of the core level mainly includes professional core courses such as Mineral Deposits, Mineral Exploration, Applied Geophysics, Applied Geochemistry, Geological Mapping Methods, and Ore Field Structural Geology. We deeply integrate intelligent exploration technology and engineering practice content into each core course to enhance the applicability and advancement of the teaching content.

In the teaching of Mineral Deposits, we add the module of "AI-assisted ore prospecting prediction", introduce the application of machine learning algorithms in ore prospecting prediction, and guide students to use geological big data and AI algorithms to carry out ore prospecting prediction practice combined with the actual ore deposit cases in Guizhou. In the teaching of Mineral Exploration, we integrate the content of "intelligent exploration project design", take the actual exploration projects of enterprises as cases, and guide students to complete the whole process of exploration project design, including project feasibility analysis, drilling layout, data processing and result evaluation. In the teaching of Applied Geophysics and Applied Geochemistry, we add the module of "digital data processing and intelligent interpretation", introduce the application of big data processing technology in geophysical and geochemical data interpretation, and guide students to use professional software to process and interpret geophysical and geochemical data. The proportion of the core level curriculum group in the total curriculum is about 30%, which is the key to cultivating students' professional core ability.

4.1.3. Expansion Level: Integrate Frontier and Cross-Disciplinary Knowledge

The expansion level is the extension of the curriculum system, which focuses on broadening students' professional vision, cultivating students' innovative ability and adapting to the diversified needs of the industry. The curriculum group of the expansion level mainly includes interdisciplinary frontier courses and comprehensive practice courses.

In terms of interdisciplinary frontier courses, aiming at the needs of green exploration and ecological governance, we offer courses such as Geological Big Data Analysis, Mine Ecological Restoration, Carbon Sink Assessment in Karst Areas, Mineral Resource Management, and Environmental Governance Regulations. For example, the course of Carbon Sink Assessment in Karst Areas combines the characteristics of Guizhou karst areas, introduces the principles and methods of karst carbon sink assessment, and guides students to carry out karst carbon sink assessment practice in typical areas of Guizhou. The course of Mine Ecological Restoration introduces the technologies and methods of mine ecological restoration, and combines the actual mine ecological restoration projects in Guizhou to carry out case teaching. In terms of comprehensive practice courses, we offer courses such as Engineering Innovation Design, Project Management, and Scientific Paper Writing, and combine the "Challenge Cup" and other scientific and technological competitions to carry out project-based learning, guiding students to complete innovative projects and cultivate their innovative ability and engineering management ability. The proportion of the expansion level curriculum group in the total curriculum is about 35%, which provides a guarantee for students' professional development and career planning.

4.2. Optimization of Practical Teaching System

Practical teaching is an important link in cultivating students' engineering practice ability, and it is also the key to the reform of the teaching content system. This study optimizes the practical teaching system of resource exploration engineering, constructs a "four-level progressive" practical teaching chain including basic practice, field practice, production practice and engineering training, and virtual simulation practice, realizing the organic combination of theory and practice, and improving the quality of practical teaching[12].

4.2.1. Basic Practice

Basic practice mainly includes experimental courses and basic skill training, which focuses on cultivating students' basic practical operation ability and experimental skills. We comprehensively transform the experimental courses from verification-based to comprehensive design-based, and increase the proportion of comprehensive design-based and innovative experiments. The proportion of comprehensive design-based experiments in the total experimental courses is increased to more than 60%.

In terms of experimental teaching reform, we integrate digital technology into experimental courses, add AI-assisted mineral identification, geological mapping simulation, digital data processing and other digital experimental links. For example, in the mineral identification experiment, we introduce AI mineral identification software, and guide students to compare the identification results of traditional methods and AI methods, so as to improve the efficiency and accuracy of mineral identification; in the geological mapping experiment, we use virtual simulation technology to simulate the geological mapping process, allowing students to carry out mapping practice in a virtual environment, which breaks the limitations of time and space. At the same time, we optimize the experimental teaching method, adopt the "experimental project-based" teaching mode, guide students to complete the experimental project independently, including experimental design, operation, data processing and result analysis, so as to cultivate students' experimental design ability and innovative thinking.

4.2.2. Field Practice

Field practice is an important part of practical teaching, which focuses on cultivating students' field work ability and geological observation ability. We optimize the field practice route, select typical geological sections in Guizhou karst areas, antimony mining areas in Duliu River basin, geological disaster sites and other regions as field practice bases, and carry out project-based field investigation.

In the field practice, we adopt the "group project system" and divide students into groups of 5–6 people. Each group is assigned a field investigation task, such as regional geological survey, profile measurement, ore body outcrop observation, and geological data sorting. Under the guidance of teachers and enterprise engineers, students complete the whole process of field investigation, including field observation, data recording, sample collection, and report compilation. At the same time, we combine the actual geological problems in the practice area, such as the geological characteristics of antimony deposits in Duliu River basin and the prevention and control of geological disasters in karst areas, to carry out special research, guiding students to apply professional knowledge to solve actual geological problems. The field practice time is increased to 4 weeks, and the practice results are included in the comprehensive evaluation of students.

4.2.3. Production Practice and Engineering Training

Production practice and engineering training focus on cultivating students' post adaptability and on-site problem-solving ability. We carry out in-depth cooperation with Guizhou Geological Mineral Bureau, large state-owned mining enterprises and environmental governance companies, and implement the "dual-tutor system" of school teachers and enterprise engineers. School teachers are mainly responsible for guiding students' theoretical learning and academic norms, and enterprise engineers are mainly responsible for guiding students' practical operation and on-site work skills.

In the production practice, students are arranged to participate in the actual engineering projects of enterprises, such as exploration project design, drilling data sorting, geological anomaly verification, environmental impact evaluation, and mine ecological restoration. They are required to participate in the whole process of the project, understand the actual work flow and technical standards of enterprises, and improve their post adaptability. In the engineering training, we invite enterprise technical backbones to carry out special training on enterprise technical standards, work skills and safety specifications, and carry out practical operation training combined with the actual work tasks of enterprises. The production practice and engineering training time is 8 weeks, and the evaluation is carried out by the joint evaluation of school teachers and enterprise engineers, with the enterprise evaluation accounting for 60%.

4.2.4. Virtual Simulation Practice

In view of the problems of high risk, high cost and poor repeatability in traditional field practice, we build a virtual simulation experiment platform for resource exploration, which covers the key links of resource exploration such as drilling layout, anomaly verification, ore body delineation, and mine ecological restoration. The virtual simulation platform uses 3D modeling technology to simulate the real geological environment and engineering scenarios, allowing students to carry out simulation operations in a virtual environment.

In the virtual simulation practice, students can simulate the process of drilling layout according to the geological data of the practice area, adjust the drilling parameters according to the drilling results, and verify the geological anomalies; they can also simulate the process of mine ecological restoration, design the restoration scheme, and evaluate the restoration effect. The virtual simulation practice not only breaks the limitations of time and space, reduces the practice cost and risk, but also allows students to carry out repeated practice, improving their practical operation ability and problem-solving ability. We integrate the virtual simulation practice into the practical teaching system, and set up 2–3 virtual simulation courses, with a total of 32 class hours.

4.3. Digital Intelligence Empowerment of Teaching Content

In order to meet the requirements of strong engineering and the digital and intelligent development trend of the geological exploration industry, we deeply integrate digital and intelligent technologies into the teaching content of resource exploration engineering, and build a digital intelligence teaching module system covering the whole curriculum, so as to improve students' digital technology application ability and intelligent exploration level.

Specifically, the integration of digital intelligence technology into teaching content mainly includes four aspects:

Integrate AI-assisted geological interpretation into Applied Geophysics and Remote Sensing Geology courses. Introduce the basic principles and methods of AI algorithms (such as machine learning, deep learning) in geophysical data inversion and remote sensing image interpretation, and guide students to use AI software to process geophysical data and remote sensing images, and carry out geological anomaly interpretation practice combined with actual cases in Guizhou karst areas.

Embed 3D geological modeling (GOCAD, Surpac) into Structural Geology and Mineral Deposits courses. Guide students to use 3D modeling software to build 3D models of stratum, structure and ore body according to geological data, and carry out spatial analysis and resource estimation, so as to improve students' spatial analysis ability and resource evaluation ability.

Apply geological big data analysis to prospectivity mapping and resource evaluation. In the courses of Mineral Exploration and Geological Big Data Analysis, introduce the collection, sorting, processing and analysis methods of geological big data, and guide students to use big data processing tools to carry out data mining and prospectivity mapping, so as to improve students' data processing ability and ore prospecting prediction ability.

Integrate intelligent exploration scheme design into Mineral Exploration courses. Take the actual intelligent exploration projects of enterprises as cases, guide students to design intelligent exploration schemes, including the selection of exploration methods, the layout of exploration equipment, and the optimization of exploration processes, so as to cultivate students' ability to design intelligent exploration schemes.

At the same time, we strengthen the construction of digital teaching resources, build a digital teaching resource library including virtual simulation courses, digital textbooks, teaching videos, and case libraries, and provide students with personalized learning resources. We also carry out mixed teaching mode reform, use online learning platforms to push digital teaching resources, carry out online discussions and online experiments, and combine offline teaching to improve the learning effect.

4.4. Digital Intelligence Empowerment of Teaching Content

In order to break the single evaluation mechanism and comprehensively reflect students' learning effect and comprehensive quality, we construct a "four-in-one" diversified comprehensive evaluation system, which includes process evaluation, result evaluation, practice evaluation and innovation evaluation. The evaluation system adopts a combination of quantitative evaluation and qualitative evaluation, and realizes full coverage and multi-dimensional evaluation of students' learning process and learning results.

Process evaluation (30%): This mainly evaluates students' learning process, including classroom performance (10%), homework completion (10%) and experimental records and learning logs (10%). Classroom performance mainly evaluates students' attendance, classroom interaction and group discussion performance; homework completion mainly evaluates the quality and timeliness of students' homework; experimental records and learning logs mainly evaluate students' experimental operation process, data recording and learning reflection.

Result evaluation (30%): This mainly evaluates students' mastery of professional knowledge and comprehensive application ability, including final examination (20%) and curriculum design/thesis defense (10%). The final examination adopts a combination of closed-book and open-book forms, focusing on examining students' core knowledge and comprehensive application ability; the curriculum design/thesis defense mainly evaluates students' engineering design ability and academic writing ability, requiring students to combine actual engineering problems to complete curriculum design or graduation thesis.

Practice evaluation (30%): This mainly evaluates students' practical operation ability and on-site problem-solving ability, including field practice assessment (15%), engineering training performance (10%) and enterprise evaluation (5%). The field practice assessment is jointly evaluated by teachers and enterprise engineers, focusing on evaluating students' field work ability and practice report quality; the engineering training performance evaluates students' practical operation skills and task completion; the enterprise evaluation evaluates students' post adaptability and work attitude during the production practice.

Innovation evaluation (10%): This mainly evaluates students' innovative ability and scientific research ability, including participation in scientific research projects (5%), discipline competitions (3%) and patent applications/academic papers (2%). Students who participate in scientific research projects at or above the university level, win awards in discipline competitions at or above the provincial level, apply for patents, or publish academic papers shall be awarded corresponding innovation assessment credits.In addition, we establish a dynamic evaluation feedback mechanism, regularly collect students' learning feedback, teachers' teaching feedback and employers' evaluation feedback, and adjust the evaluation indicators and weight distribution in a timely manner to ensure the scientificity and rationality of the evaluation system.

5. Implementation Path and Safeguard Measures

In order to ensure the smooth implementation of the teaching content system reform and achieve the expected reform effect, we formulate a clear implementation path and improve the corresponding safeguard measures from three aspects: teacher team construction, industry-education collaborative platform construction, and resource and system safeguards.

5.1. Teacher Team Construction

The teacher team is the core force of teaching reform, and the quality of the teacher team directly affects the effect of teaching reform. We focus on building a high-quality "double-qualified" teacher team with strong engineering practice ability, high professional level and rich teaching experience, and adopt the measures of "introduction, training and integration" to improve the overall quality of the teacher team.

Promote the training of "double-qualified" teachers: Every year, we arrange 5–8 young and middle-aged teachers to take temporary posts in geological teams, mining enterprises and environmental governance companies, participate in the actual engineering projects of enterprises, and accumulate engineering practice experience. At the same time, we organize teachers to participate in training courses on digital intelligence technology, engineering education reform and other aspects, and improve teachers' digital technology application ability and teaching level[13-14].

Invite senior engineers and technical backbones from enterprises to serve as part-time teachers: We establish a part-time teacher resource library, invite senior engineers and technical backbones from Guizhou Geological Mineral Bureau, large state-owned mining enterprises and other units to serve as part-time teachers, participate in curriculum teaching, practice guidance and curriculum design, and bring the latest industry technology standards and actual project experience into the teaching process.

Establish cross-disciplinary teaching teams: We establish cross-disciplinary teaching teams including geology, data science, environmental engineering and management science, carry out teaching research and curriculum development, and promote the integration of interdisciplinary knowledge into professional teaching. At the same time, we carry out teaching and research activities regularly, organize teachers to exchange teaching experience and reform ideas, and improve the team's overall teaching and research level.

After three years of construction, the proportion of "double-qualified" teachers in the resource exploration engineering major has increased from 35% to 68%, and the number of teachers participating in enterprise projects has increased by 50% annually, which provides a strong talent guarantee for the smooth implementation of teaching reform.

5.2. Industry-Education Collaborative Platform

Industry-education integration is the key to improving the quality of practical teaching and narrowing the gap between talent training and enterprise demand. We focus on building an industry-education collaborative platform, and carry out in-depth cooperation with enterprises in curriculum construction, practice base construction, scientific research and other aspects.

Jointly build practice bases, curriculum systems and training programs with geological bureaus, mining enterprises and environmental governance institutions: We have built 12 stable practice bases with Guizhou Geological Mineral Bureau, Guizhou Nonferrous Metals Geological Exploration Bureau and other units, and formulated detailed practice teaching plans and evaluation standards together with enterprises. At the same time, we jointly develop curriculum systems and training programs with enterprises, and integrate enterprise technical standards and actual project requirements into the curriculum content.

Jointly develop characteristic textbooks and teaching cases with real engineering projects as the carrier: We organize school teachers and enterprise engineers to jointly compile characteristic textbooks such as “Intelligent Exploration Technology of Mineral Resources” and “Mine Ecological Restoration in Karst Areas”, which integrate a large number of actual enterprise projects and industry technical standards. At the same time, we build a teaching case library, collect typical engineering cases in the geological exploration industry, and use them in classroom teaching and practical training.

Promote the transformation of scientific research achievements into high-quality teaching resources: We carry out joint scientific research with enterprises on key technologies such as intelligent prospecting, mine ecological restoration and karst carbon sink assessment, and transform the scientific research achievements into teaching resources such as teaching videos, experimental projects and virtual simulation courses, realizing the benign interaction between scientific research and teaching[15-16].

5.3. Resource and System Safeguards

In order to provide sufficient support for the teaching content system reform, we strengthen the construction of teaching resources and improve the corresponding supporting systems.

Increase investment in digital experimental equipment, virtual simulation resources and industry-university cooperation platforms: We have invested more than 5 million yuan to purchase digital experimental equipment such as 3D scanners, geological data processing workstations and AI interpretation software, and built a virtual simulation experiment platform for resource exploration. At the same time, we increase investment in industry-university cooperation platforms, and provide financial support for the joint construction of curriculum, practice bases and scientific research projects with enterprises.

Improve the supporting systems such as curriculum management, practical teaching process norms and performance evaluation: We formulate and improve the “Curriculum Management Measures”, “Practical Teaching Management Measures”, “Teacher Performance Evaluation Measures” and other systems, standardize the teaching process and evaluation standards, and provide a system guarantee for the smooth implementation of teaching reform.

Establish a dynamic adjustment mechanism of teaching content: We regularly carry out industry research and employer demand investigation, track the latest development trends of the geological exploration industry and the update of technical standards, and update the knowledge modules and practical projects of the curriculum in a timely manner. At the same time, we collect students’ learning feedback and teachers’ teaching feedback, and adjust the curriculum content and teaching methods in a timely manner to ensure that the teaching content system is always consistent with the needs of the industry and students.

6. Effect Analysis of Reform Practice

The reform scheme of the teaching content system of resource exploration engineering has been implemented for three consecutive years in Guizhou Institute of Technology and four other cooperative universities. In order to verify the reform effect, we carry out a comprehensive evaluation from four dimensions: students’ professional ability improvement, employment competitiveness enhancement, employer satisfaction evaluation and teaching quality improvement. The evaluation data are mainly from the statistical results of student ability tests, employment data, employer questionnaires and teaching supervision evaluations.

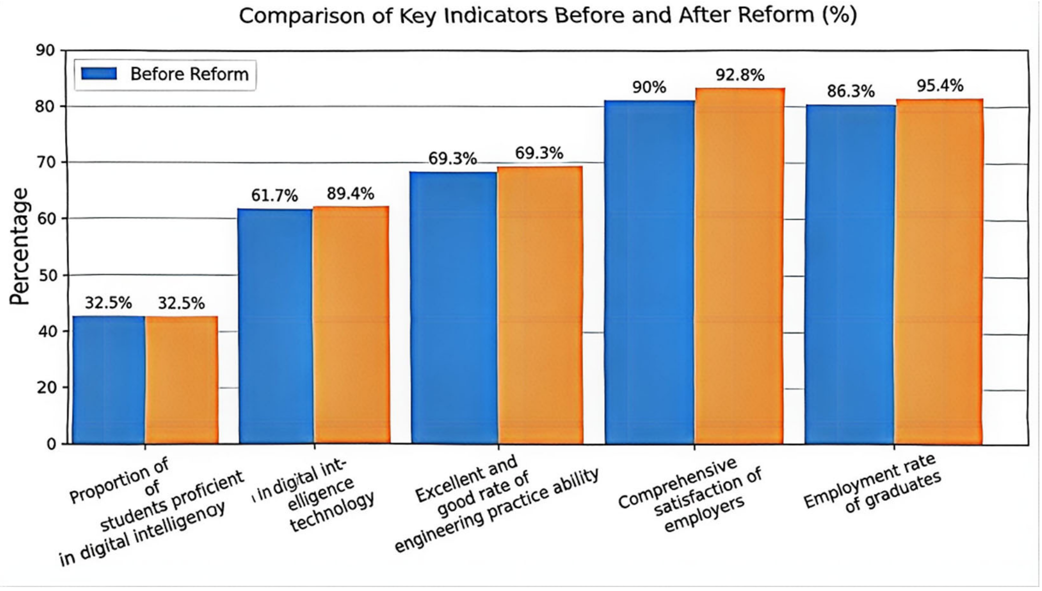

Figure 1. Comparison chart of key indicators before and after the reform of resource exploration engineering teaching content system

6.1. Improvement of Students' Professional Ability

After three years of reform, students' professional ability has been significantly improved, especially in digital intelligence application ability and engineering practice ability. The statistical results show that the proportion of students who can skillfully use digital intelligence technologies such as 3D geological modeling, AI-assisted geological interpretation and geological big data processing has increased from 32.5% before the reform to 86.3% after the reform; the excellent and good rate of engineering practice ability evaluation has increased from 61.7% before the reform to 89.4% after the reform.

In terms of scientific research and innovation ability, the number of students participating in scientific research projects has increased from 28% before the reform to 65% after the reform; the number of awards in national and provincial geological skills competitions has increased by 42% annually. For example, in 2024, students majoring in resource exploration engineering won 3 national awards and 8 provincial awards in the National College Students' Geological Skills Competition, which is a significant increase compared with before the reform. At the same time, the number of students applying for patents and publishing academic papers has also increased significantly, with 12 patents applied for and 8 academic papers published in three years.

6.2. Enhancement of Employment Competitiveness

The reform has effectively improved the employment competitiveness of graduates, and the employment quality and employment rate have been significantly improved. The statistical results show that the employment rate of graduates has remained above 95% for three consecutive years, increasing from 90% before the reform to 95.5% after the reform. In terms of employment quality, the proportion of graduates employed in key enterprises such as provincial geological brigades, large state-owned mining enterprises and environmental governance companies has increased from 48% before the reform to 76% after the reform; the average starting salary of graduates has increased by 28% compared with before the reform, which is 15% higher than the average starting salary of graduates of the same major in the province.

In addition, the proportion of graduates pursuing postgraduate studies in well-known universities at home and abroad has also increased significantly, from 12% before the reform to 25% after the reform. Most of these postgraduates are admitted to key universities with strong geological disciplines such as China University of Geosciences (Wuhan), China University of Geosciences (Beijing), and Guizhou University, and their research directions are mainly focused on digital intelligent exploration, mine ecological restoration, karst carbon sink assessment and other frontier fields, which are highly consistent with the reform direction of the major and the development needs of the industry. This fully shows that the reform of the teaching content system has effectively improved the comprehensive quality and employment competitiveness of graduates, and has laid a solid foundation for their career development.

6.3. Evaluation of Employer Satisfaction

Employer satisfaction is an important indicator to measure the effect of talent training. Through the follow-up investigation of employers who have recruited graduates of resource exploration engineering in the past three years, it is found that the comprehensive satisfaction of employers with graduates has increased from 69.3% before the reform to 92.8% after the reform, which has increased by 23.5 percentage points. Specifically, 94.1% of employers believe that graduates have strong engineering practice ability and can quickly adapt to post work; 89.7% of employers affirm the digital intelligence application ability of graduates, and believe that graduates can skillfully use digital intelligent technologies to carry out exploration work, which effectively improves work efficiency; 87.2% of employers believe that graduates have good professional quality and teamwork spirit, and can better cooperate with the team to complete engineering tasks.

Many employers have given positive feedback on the graduates trained after the reform, and have established long-term cooperative recruitment relations with our university. For example, Guizhou Geological Survey Bureau pointed out in the feedback that “the graduates of resource exploration engineering have strong practical ability and digital literacy, can quickly master the on-site work skills, and have made important contributions to the local geological exploration work”. Guizhou Nonferrous Metals Geological Exploration Bureau also said that “the graduates have a solid professional foundation and innovative thinking, and can effectively apply new technologies and new methods to solve practical engineering problems, which is highly consistent with the enterprise’s talent demand”.

6.4. Improvement of Teaching Quality

The reform of the teaching content system has also effectively promoted the improvement of the overall teaching quality of the major. In terms of curriculum construction, 5 core courses of the major have been rated as provincial excellent courses, and 3 courses have been included in the provincial online and offline mixed teaching reform pilot projects. The characteristic textbooks jointly compiled by school teachers and enterprise engineers have been adopted by 8 colleges and universities in the province, and have been highly recognized by peers. In terms of teaching research, teachers of the major have undertaken 12 provincial and above teaching reform projects, published 18 teaching research papers, and won 6 provincial and above teaching achievement awards, which has significantly improved the teaching and research level of the teacher team.

In addition, the school’s teaching supervision evaluation results show that the excellent rate of classroom teaching quality of the major has increased from 72% before the reform to 91% after the reform; the satisfaction of students with the curriculum system and teaching content has increased from 65% before the reform to 88% after the reform. The reform has not only optimized the teaching content and teaching methods, but also promoted the transformation of teachers' teaching concepts, realized the organic combination of teaching and scientific research, and formed a good teaching atmosphere of "teaching promotes research and research feeds back teaching".

7. Conclusion

Under the background of strong engineering construction and national control major standardization management, this study takes resource exploration engineering as the research object, based on the OBE education concept, new engineering education theory and industry-education integration theory, systematically constructs a teaching content system reform framework of "four-dimensional integration, three-level progression, digital intelligence empowerment and diversified evaluation", and carries out in-depth reform practice from curriculum system reconstruction, practical teaching optimization, digital intelligence empowerment, diversified evaluation construction and other aspects.

The three-year reform practice shows that the reform scheme is scientific, feasible and effective. After the reform, the curriculum system is more reasonable, the practical teaching is more targeted, the digital intelligence level of teaching content is significantly improved, and the diversified evaluation system is basically formed. The professional ability, innovative ability and employment competitiveness of students have been significantly improved, the satisfaction of employers has been greatly improved, and the overall teaching quality of the major has been comprehensively upgraded. The reform has effectively solved the prominent problems such as aging teaching content, insufficient integration of digital intelligence technology, weak practical teaching and single evaluation mechanism in the traditional teaching content system of resource exploration engineering, and realized the transformation and upgrading of the talent training mode of the major.

The research results show that the reform of the teaching content system of resource exploration engineering must adhere to the demand orientation, take the cultivation of compound engineering talents with strong practical ability, innovative thinking and digital literacy as the goal, closely combine with the development trend of the industry and the actual needs of employers, and realize the deep integration of theoretical teaching and practical training, digital intelligence technology and professional knowledge, industry and education resources, and ideological and political education and professional teaching. At the same time, it is necessary to strengthen the construction of teacher teams, build industry-education collaborative platforms, and improve resource and system safeguards to ensure the smooth implementation of the reform.

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2024 Annual Undergraduate Teaching Content and Curriculum System Reform Project of Institutions of Higher Education in Guizhou Province "Research on the Reform of Teaching Content System of the New National Controlled Major - Resource Exploration Engineering under the Background of Strong Engineering" (GZJG2024218)

References

[1] Ministry of Education of the People's Republic of China. List of Newly Adjusted National Control Undergraduate Majors (2023–2025) [Z], 2023.

[2] J. Li, H. Wang. Reform and Practice of National Control Majors Under the Background of New Engineering, Journal of Higher Education, vol. 45 (2024) No. 7, p.102-107.

[3] L. Zhang, Y. Chen. Construction Path of Strong Engineering in Local Engineering Colleges and Universities, Research in Higher Education of Engineering, (2023) No. 4, p.56-62.

[4] Z. Wang, X. Li. Problems and Countermeasures of Teaching Content System Reform for Resource Exploration Engineering, Journal of China University of Geosciences (Social Sciences Edition), vol. 22 (2022) No. 3, p.145-152.

[5] F. Chen, Y. Zhao. Research on the Reform of Practical Teaching System for Resource Exploration Engineering Based on Industry-University Integration, Experimental Technology and Management, vol. 39 (2022) No. 8, p.234-238.

[6] Outcome-Based Education (OBE) Steering Committee. Guidelines for OBE Implementation in Engineering Education [M], Beijing: Higher Education Press, China 2021.

[7] C. Lin, J. Huang. New Engineering Construction and Teaching Reform of Traditional Engineering Majors, Journal of Engineering Education, (2023) No. 2, p.78-85.

[8] H. Liu, Q. Zhang. Research on Industry-University Integration Mechanism of Resource Exploration Engineering Under the Background of Strong Engineering, China University Teaching, (2024) No. 3, p.89-94.

[9] Guizhou Provincial Department of Natural Resources. Guizhou Provincial Mineral Resources Development Report (2023) [R], Guiyang: Guizhou Provincial Department of Natural Resources, 2024.

[10] P. Wang, J. Li. Application of Digital Intelligence Technology in Resource Exploration Engineering Teaching, Geological Science and Technology Information, vol. 42 (2023) No. 4, p.289-296.

[11] S. Zhang, L. Wang. Construction of Diversified Evaluation System for Resource Exploration Engineering Based on OBE Concept, Higher Education Research, vol. 43 (2022) No. 11, p.89-95.

[12] Ministry of Education of the People’s Republic of China. Guidelines for the Construction of National Control Undergraduate Majors [Z], 2023.Z.W. Zhang, J.N. Wang: Crane Design Manual (China Railway Press, China 1998), p.683-685. (In Chinese)

[13] C. Li, W.Q. Yin, X.B. Feng, et al. Brushless DC motor stepless speed regulation system based on fuzzy adaptive PI controller, Journal of Mechanical & Electrical Engineering, vol. 29 (2012), 49-52.

[14] China National Standardization Management Committee. Specifications of Crane Design (China Standardization Press, China 2008), p. 16-19.

[15] J. Liu, E.L. Chen and Z.T. He: Journal of Shi Jia Zhuang Railway Institute (Natural Science), Vol. 22 (2009) No. 4, p.40-42.

[16] Q. D. Zeng, Q. E. Li: Progress in Civil Engineering, Vol. 32 (2012) No. 9, p. 3077-3080.