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Exploration of Non-technical Ability Cultivation in Engineering Education Professional Certification under Background of New Engineering Disciplines

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Abstract: *It studies the cultivation of non-technical abilities in engineering education professional certification under background of new engineering disciplines, and analyzes the importance of non-technical abilities in cultivating high-quality composite engineering talents. In response to the current problems in non-technical ability training, the three main training plans have been proposed: Firstly, it effectively decomposes the graduation requirements indicators of non-technical abilities through the enterprise research, and constructs a strong support training system for the professional course classification; Secondly, it organically integrates the non-technical abilities into the collaborative training of the technical skills in big data professional courses; Thirdly, it adopts the diverse forms of professional practical activities outside of class to achieve the sustainable cultivation of non-technical abilities. The application effect shows that through the implementation of the above training program, students majoring in Data Science and Big Data Technology have achieved significant results in the application for innovation projects and subject competitions, effectively improving the non-technical abilities and comprehensive literacy to cultivate high-quality composite engineering talents with international competitiveness.*

Keywords: *Engineering education; Professional certification; Non-technical abilities*

1. Introduction

Since 2017, the concept of "New Engineering" has been proposed and gradually gained the widespread influence. The Ministry of Education actively promotes the construction of new engineering disciplines and has successively formed guiding documents such as the "Fudan Consensus", "Tianda Action", and "Beijing Guidelines". The development of the new economy has posed challenges to the cultivation of traditional engineering professionals. In the future, the emerging industries and the new economy require high-quality composite "new engineering" talents with strong engineering practice ability, innovation ability, and international competitiveness. The aim is to cultivate excellent engineers for China's future industrial field, rather than the important literacy of excellent engineers above the technical level, which is based on technical elements. Engineering education professional certification is not only an internationally recognized quality evaluation system for engineering education talent cultivation, but also an important way to achieve international mutual recognition of engineering education and engineering qualifications. It has played a pivotal role in the development of higher education and has now become an internationally recognized quality evaluation system for engineering education talent cultivation. In June 2016, China officially joined the Washington Accord, marking the international substantive equivalence of China's engineering education quality standards. Based on the engineering education professional certification standards implemented by member countries of the Washington Accord, the abilities possessed by engineering graduates can be divided into two categories: technical abilities and non-technical abilities. Since the launch of engineering education professional certification in China is in 2006, domestic educators and educational management researchers have conducted extensive and in-depth research on the cultivation of students' technical abilities. There is a highly consistent understanding among higher engineering education researchers both domestically and internationally regarding the importance of cultivating non-technical abilities in engineering education: non-technical abilities play an equally important role as technical abilities in students' future career development. The graduation requirements of the American ABET certification standards and China's "Engineering Education Professional Certification

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Standards (2015)" also explicitly mention the importance of non-technical abilities such as effective communication skills, lifelong learning abilities, professional ethics, and social responsibility [1-2].

The 2020 edition of the General Standards for Engineering Education Interpretation and Usage Guidelines provides a detailed interpretation of the 12 graduation requirements, including the graduation requirements related to non-technical abilities in Articles 6-12. The Washington Accord proposes 12 engineering education certification standards for higher engineering talent based on the concept of big engineering. Among them, 7 out of 12 certification standards are for the cultivation of non-technical abilities, namely engineering and society, environment and sustainable development, professional norms, individual and team, communication, project management, and lifelong learning. In the latest version of the Washington Accord (2021), Article 7 "Environment and Sustainable Development" has been merged into Article 6 "Engineering and Society" to form a new Article 6 "Engineering and the World". In recent years, scholars at home and abroad have conducted rich research on the main content, importance, evaluation methods, and future innovative development of non-technical ability cultivation and evaluation in engineering education. In references [3-4], a method is proposed to synergistically cultivate technical and non-technical abilities through engineering internship teaching. In the literature [5], taking practical training courses as an example, micro courses, "Internet plus" and other information-based means are comprehensively used to cultivate and exercise students' non-technical abilities. Starting from the design of the curriculum system, literature [6-10] explores how to cultivate and evaluate non-technical abilities. According to the characteristics of practical teaching in reference [11], a multi index supported practical teaching system framework is constructed. In references [12-15], it is explored to enhance students' non-technical abilities through improving teaching modes and other methods. Based on the talent cultivation practice of Beijing Institute of Technology, reference [16] proposes a non-technical ability improvement and cultivation path of "one responsibility, three trimers, and four evaluations". In reference [17], the relying on the innovation practice platform for college students effectively improved their non-technical abilities. Reference [18] analyzed the supportive role of participating in subject competitions in the cultivation of non-technical abilities, and proposed the use of various strategies such as guidance, coercion, encouragement, and motivation combined with the curriculum system to organize students to participate and effectively cultivate their non-technical abilities. Reference [19] proposed a strategy for cultivating students' non-technical abilities based on blended online and offline teaching. References [20-21] proposed non-technical ability cultivation concepts based on "human culture," "humanization," "dynamism," and "flexibility," achieving a transformation of non-technical ability cultivation concepts based on curriculum ideological and political reform.

In the new era and new requirements of undergraduate education in the "New Engineering" field, the training standards for innovative engineering talents are certified by engineering majors, in addition to cultivating college students' mastery of professional knowledge, basic skills, and professional abilities. They must also possess the ability to adapt to social, era development, market economy, and global challenges. In this sense, the non professional ability training is more profound for the development and success of college students than the professional ability training. With the continuous development of science and technology and the arrival of the globalization era, the demand for composite engineering talents in society is increasing day by day, and higher requirements have been put forward for non-technical ability levels in higher engineering education. How to integrate non-technical ability training into natural science, engineering, and professional courses of technical ability training, how to decompose the graduation requirements indicators of non-technical ability training to provide strong support for professional course classification, and how to explore innovative practical methods for non-technical ability training according to the characteristics of different student groups have become an important issue in higher engineering education research and exploration. The emphasizing the cultivation of students' engineering practical ability and comprehensive engineering quality, especially strengthening the cultivation of non-technical abilities, is of great practical significance for improving the quality of the applied talent cultivation.

2. Current Problems in Non-technical Ability Cultivation

Research is conducted on the cultivation of non-technical abilities in engineering education professional certification under the background of "new engineering disciplines". it focuses on how to effectively decompose the graduation requirements indicators of non-technical abilities based on the actual needs of non-technical talents surveyed by enterprises and achieve strong support training with professional course classification, how to naturally integrate non-technical ability elements into collaborative training in big data technology capability development, and how to conduct project-based

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teaching based on actual cases in professional courses. And for different student groups and individuals, it is also necessary to tailor measures according to their needs. It is important to use various methods such as big data training camps, project-based activities, college student innovation and entrepreneurship training programs, big data subject competitions, etc. to sustainably cultivate non-technical abilities.

2.1 Effective Decomposition of Graduation Requirements Indicators for Non-technical Abilities through Enterprise Research, and Construction of Strong Support Training for Professional Course

Based on the actual demand for non-technical talent in enterprise research, it effectively decomposes the graduation requirements indicators for non-technical skills, classifies the benchmark table for non-technical skills through matching, and further explores the relevant sub indicators of various graduation requirements indicators for non-technical skills. By analyzing the non-technical ability elements that strongly support the cultivation of various professional courses in big data, it constructs a training relationship matrix between the graduation requirements indicators of various professional courses and non-technical abilities, and fully considers the curriculum system in the big data professional training plan, especially the core courses and directional courses. It breaks the classification of existing curriculum modules, and classifies non-technical ability professional courses according to the training objectives and characteristics of professional courses. It coordinates and balances the mapping relationship between the non-technical ability training indicators of the entire major in engineering education certification and the graduation requirements indicators of non-technical abilities in various professional courses, in order to meet the graduation requirements indicators of non-technical abilities in engineering education certification. It further implements the cultivation of non-technical abilities through various professional courses, and researches the decomposition and classification of non-technical abilities in professional courses.

2.2 Organic Integration of Non-technical Skills for Collaborative Training in the Technical Ability Development of Big Data Professional Courses

In actual teaching, a hierarchical integrated teaching approach of "three steps" is carried out through the use of low, medium, and high-level cases to encourage and inspire students to think more in case analysis. Through the three stages of the learning and practicing, the practicing and thinking, and the thinking and editing, students can achieve an orderly process of improving their abilities from imitation, expansion to transcendence. At the same time, students are encouraged and guided to ask more questions in the group discussions of cases, actively express their own opinions and views, and improve their non-technical abilities such as communication, unity, coordination, and teamwork in team development through project-based inquiry based on teaching methods such as case breaking, brainstorming, self-expression, student student interaction, and teamwork.

2.3 Adopt Diverse Extracurricular Professional Practice Activities to Achieve the Sustainable Cultivation of Non-technical Abilities

Students have different learning foundations and interests, which results in the significant differences in their enthusiasm for learning. Based on the characteristics and actual learning situation of each student, they can voluntarily choose to participate in various professional practice activities such as big data training camps, project-based activities, college student innovation and entrepreneurship training projects, big data subject competitions, etc., in groups to expand their professional horizons. It can improve their self-learning and team cooperation abilities, and provide professional space for students who have spare capacity for self-study and in-depth learning. In the design of project cases, the different difficulty levels of topics can be selected for students at different levels of foundation to ensure a certain degree of learning and growth space for students. By adopting diverse student training methods, the sustainable non-technical skills development is achieved while enhancing technical abilities.

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3. Non-technical Ability Training Program

3.1 Classification and Training Plan for Non-technical Abilities in Data Science and Big Data Technology Major Courses

Through visiting and investigating many enterprises such as CNKI, ByteDance, AsiaInfo Technology and Capgemini Group, we have a face-to-face in-depth understanding of the changing trend of enterprise talent demand, the current situation of the industry and the future development trend, which provides a favorable guarantee for the development of professional training programs. It can fully integrate the research of big data enterprises to effectively decompose the graduation requirements indicators of non-technical abilities, and then construct a strong support training for professional course classification. Graduates of this major should achieve non-technical ability indicators 6-12, and the supporting relationship between the compulsory course system of Data Science and Big Data Technology and the graduation requirements for non-technical abilities 6-12 is shown:

Indicator 6. Engineering and Society: Able to conduct reasonable analysis based on engineering related background knowledge, evaluate the impact of professional engineering practices and complex engineering problem solutions on society, health, safety, law, and culture, and understand the responsibilities that should be undertaken (Fundamentals of Engineering and Social Computer Networks, Discrete Mathematics, Principles of Statistics, Data Analysis and Practice).

Indicator 7. Environment and Sustainable Development: Able to understand and evaluate the impact of engineering practices targeting complex engineering problems in the field of big data on environmental and social sustainable development (Principles and Practice of Environment and Sustainable Development Data Warehouse, University Physics, Web Front end Framework Technology, Real time Big Data Computing).

Indicator 8. Professional Standards: Possess good ideological and moral qualities, humanities and social science literacy, and a sense of social responsibility, and be able to actively practice and abide by professional ethics and standards in engineering practice (Fundamentals of Programming, Object Oriented Programming, Python Scientific Computing, Web Crawler and Data Collection).

Indicator 9. Individuals and Teams: Possess a sense of teamwork and be able to clearly define the roles of individuals, team members, and leaders in interdisciplinary, cross disciplinary, and multi team situations (Data Visualization Technology, Web Front-end Technology and Practical Experience, JavaEE Cloud Development Technology).

Indicator 10. Communication: Able to effectively communicate and interact with industry peers and the public on complex engineering issues, including writing reports and design documents, making statements, and clearly expressing or responding to instructions. And possess a certain international perspective, able to communicate and exchange ideas in cross-cultural contexts (Principles and Applications of Communication Database, NoSQL Database Practice, Open Source Big Data Platform Technology, Alibaba Big Data Technology and Applications).

Indicator 11. Project Management: Understand and master the principles of engineering management and economic decision-making methods, and be able to apply them in a multidisciplinary environment (Linux Operating System, Data Structures, and Comprehensive Practical Experience of Enterprise Projects).

Indicator 12. Lifelong Learning: Possess awareness of self-directed and lifelong learning, and have the ability to continuously learn and adapt to development (Advanced Mathematics, Linear Algebra, Probability Theory and Mathematical Statistics, and Principles of Machine Learning Algorithms).

The non-technical ability classification training plan for the data science and big data technology major courses mentioned above aims to meet the needs of the new national strategic development in the big data era, cultivate comprehensive development in morality, intelligence, physical fitness, and aesthetics, adhere to the correct political direction, possess good professional ethics and personal cultivation, master professional knowledge such as big data theory, technology, and methods, have certain data thinking and computational thinking, be familiar with the collection, storage, development, analysis, and visualization aspects of the big data industry, and be applied talents who can engage in big data analysis, big data development, and other positions in the field of big data engineering.

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3.2 Collaborative Training Plan Iintegrating Non-technical Abilities into the Technical Ability Development of Professional Courses

Taking the core course "Principles of Machine Learning Algorithms" in the field of big data as an example, the course objective is to enable students to:

Course objective 1: To be able to apply machine learning algorithm principles to solve complex big data engineering problems and conduct algorithm evaluations.

Course objective 2: To be able to seek machine learning algorithm solutions for complex engineering problems in the field of big data through research and analysis of literature, and to possess the ability to analyze, compare, and evaluate multiple algorithms.

Course objective 3: To be able to apply machine learning algorithm principles, select appropriate algorithms based on data characteristics and research objectives for analysis, modeling, and model evaluation, and obtain reasonable and effective conclusions.

Course objective 4: To be able to self learn and research machine learning algorithms, continuously adapt to the development of big data engineering technology and social needs.

The supporting relationship between course objectives and graduation requirements is shown:

Course objective 1(1. Engineering knowledge):1.4 Ability to apply professional knowledge to compare and synthesize solutions to complex big data engineering problems.

Course objective 2(2. Problem analysis):2.2 Ability to seek solutions to complex engineering problems in the field of big data through research and analysis of literature. Ability to analyze, compare, and evaluate multiple solutions to complex engineering problems in the field of big data).

Course objectives 3(4. Research):4.2 To be able to apply basic theories and methods of data modeling, data management and analysis, and statistical inference, select research routes based on data characteristics and research objectives, conduct analysis modeling and model evaluation, and obtain reasonable and effective conclusions).

Course objective 4(12. Lifelong learning):12.2 To be able to establish plans and goals that are suitable for one's own development, adopt appropriate methods for self-learning, and continuously adapt to the development of big data engineering technology and social needs).

Course objectives 1-3 are the graduation requirements for technical abilities, while course objective 4 is the graduation requirements for non-technical abilities. This course aims to cultivate both abilities in a collaborative manner.

This course is aimed at the course objectives and mainly adopts various teaching methods such as lecture, demonstration, project driven, inspiring, practice, and classroom discussion to fully mobilize students' enthusiasm. In the theoretical part of the teaching unit, a mixed online and offline teaching mode is mainly adopted. Before class, PPT, key videos and other materials are used to help students preview the course content. In class, teaching methods such as lecturing, inspiration, case teaching and classroom quizzes are used to deepen students' understanding of the principles of machine learning algorithms. After class, mind maps and practice assignments are used to help students consolidate their knowledge points; For practical teaching, various forms such as project driven method, demonstration method, inspiration method, classroom discussion, and extracurricular exercises are mainly adopted to cultivate students' ability to research solutions and use modern tools and resources in solving complex engineering problems; In addition, the course also cultivates and enhances students' professional communication skills through forms such as writing experimental reports and conducting oral presentations for defense. Through the course objectives and implementation examples of the above professional courses, the technical ability cultivation of data science and computer technology courses will be integrated with non-technical abilities for collaborative cultivation. Furthermore, the top 5 technical abilities (engineering knowledge, problem analysis, design/development solutions, research, modern tool use) and the bottom 7 non-technical abilities (engineering and society, environment and sustainable development, professional norms, individual and team, communication, project management, lifelong learning) of graduation requirements will be further integrated to cultivate the comprehensive literacy of students in this major, enhance their professional theoretical level and practical ability, and enable professional technical ability and non-technical ability to grow together.

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3.3 Sustainable Cultivation Plan for Non-technical Abilities Based on Extracurricular Professional Practice Activities

Through various extracurricular professional practice activities such as big data training camps, project-based activities, college student innovation and entrepreneurship training programs, and big data subject competitions, on the one hand, the comprehensive practical application and in-depth expansion of professional abilities are carried out, and on the other hand, the comprehensive training and enhancement of non-technical abilities are comprehensively developed and enhanced. In this way, the collaborative cultivation of technical and non-technical abilities in class can further promote the sustainable development of non-technical abilities outside of class. In extracurricular professional practice activities, student studios are the main focus and open to all students in various majors of all grades. Student studios mainly adopt a team project system, which can be combined with the application, mid-term, and final stages of college students' innovation and entrepreneurship training projects, as well as the incubation and cultivation of subsequent projects. They can also be guided by the problem-solving, design ideas, solutions, and optimization of big data professional subject competitions, in order to sustainably cultivate students' non-technical abilities such as self-learning, teamwork, collaborative communication, and lifelong learning in solving practical problems. It is a specific training explanation by using the metadata studio as an example:

The metadata studio relies on the Soft Information Teaching and Research Office of the Information Science Department of Beijing City University, and is engaged in the analysis and research of intelligent service applications related to data mining and machine learning for big data and artificial intelligence, which can provides students with an innovative practical training platform. The focus is on cultivating students' self-learning and innovative practical abilities to enhance their comprehensive application abilities in data processing, analysis, modeling, evaluation, prediction, and visualization, which can provides support for applying for innovation and entrepreneurship projects, participating in social practice and various subject competitions, and laying a foundation for students to engage in work related to big data analysis in the future. The metadata studio provides interdisciplinary and integrated training for students in multiple majors such as big data, software engineering, computer science, and the internet of things. It fully combines students' learning interests to carry out multiple intelligent software and hardware research groups such as data mining and machine learning. Regular salon exchange activities are held inside and outside the studio for interdisciplinary learning. And it is to plan for students to undergo in-depth professional growth and development from their freshman, sophomore, and junior years, which can create a scenario based learning ecosystem for real work in enterprises.

Freshman Engineering Cognitive Project: Based on relatively simple virtual projects, it will guide students to learn the basic knowledge and techniques of big data analysis, familiarize themselves with the characteristics of big data engineering and analysis processes.

Second year practical training project: With the innovation and entrepreneurship project for college students as the main line, it will organize students to complete tasks in a team form, comprehensively exercise students' teamwork ability, and require students to have standardized code, complete processes, and standardized documents.

Third year subject competition projects: It will encourage students to participate in various subject competitions such as the National College Student Big Data Analysis Technology Competition, China College Student Computer Design Competition, China College Student Challenge Cup, etc., and provide support such as competition information, pre competition training, and team guidance.

Actual practical projects: Under the guidance of both school and enterprise mentors, students can enter the practice of social service projects. Through practical project training in enterprises, students not only become familiar with the analysis process of enterprise projects, but also learn advanced technologies and applications in the industry, and cultivate and improve their self-learning ability and ability to solve complex practical problems, which can lay a solid foundation for their ultimate employment.

Students can engage in the in-depth and interdisciplinary studio learning and development based on their actual learning needs. By this way, they can actively participate in various project teams and effectively improve their non-technical abilities while developing their technical skills. The student studio mainly adopts project-based activities for learning and cultivation, so that students from different majors and classes can fully communicate and learn, and comprehensively improve non-technical abilities through technical skills in actual projects. Compared with the cultivation of non-technical abilities in class, the cultivation in class is limited by the scope of knowledge points in a certain course,

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while the extracurricular professional practice activities involve a wider range of professional knowledge and can involve interdisciplinary and professional intersections. The comprehensiveness and practicality of the entire extracurricular activity project are relatively high. In fact, in the extracurricular professional practice activities, students' non-technical abilities can be better comprehensively improved, and thus the cultivation of non-technical abilities in class can be developed into a more in-depth and extensive sustainable cultivation of non-technical abilities outside of class.

4. Application Effect of Non-technical Ability Cultivation

The research is applied to the major of Data Science and Big Data Technology. By conducting research on big data enterprises, we can effectively decompose the graduation requirements indicators for non-technical abilities, construct strong support training for professional course classification, form a non-technical ability classification training plan for data science and big data technology professional courses, and implement the training for this major; In the cultivation of technical abilities in various professional courses of big data, non-technical abilities are organically integrated for collaborative cultivation by forming a collaborative cultivation plan that integrates non-technical abilities into the technical ability cultivation of professional courses and implementing it in the teaching of this professional course; It adopts diverse forms of extracurricular professional practice activities to achieve sustainable cultivation of non-technical abilities, forms a non-technical ability sustainable cultivation plan based on extracurricular professional practice activities, and implements it in the training of students in this major. Through the implementation of the training program for students majoring in Data Science and Big Data Technology, students have actively and successfully applied for more than 10 major innovation projects in 2024 and completed more than 10 major innovation projects in 2023. Students also actively participate in relevant subject competitions, and win 2 sets of third prizes in the national competition, 3 sets of first prizes in the provincial competition, 2 sets of second prizes, and 3 sets of third prizes in the big data track of the computer design competition, 1 second prize and 2 third prizes in the National College Students Big Data Analysis Technology Skills Competition, as well as 4 first prizes, 5 second prizes, and 9 third prizes in the provincial competition.

5. Conclusions

In response to the issue of cultivating non-technical abilities in engineering education professional certification under the background of "new engineering disciplines", the graduation requirements were compared, and non-technical abilities that fully combined with the actual needs of job talents surveyed by enterprises were decomposed and classified in the table. The course modules of the big data professional training program were broken down and reclassified to achieve the classification and cultivation of non-technical abilities in professional courses. In terms of innovative teaching methods, based on the professional course design concept of project-based case teaching, a step-by-step approach is adopted to inspire students to think and solve problems; In terms of creating teaching environments, it is to actively carry out team project based case-based inquiry based teaching, and use group discussions to simulate project team development in the actual working environment of enterprises; In terms of teaching evaluation reform, the process integration of case thinking and discussion is adopted to incentivize the evaluation of students' daily performance, encourage more thinking to solve case problems, and fully leverage the collaborative efforts in the project team.

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