Evaluation of Innovative Ability in Engineering Students

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Abstract: This study aims to explore the evaluation system for assessing the innovative ability of engineering students, providing theoretical support and practical guidance for higher education institutions. Through a systematic review and analysis of existing literature, this paper constructs an evaluation framework based on five dimensions of innovative ability (creative thinking, problem-solving skills, teamwork, technical application, and autonomous learning), considering the characteristics of engineering education. Utilizing the Delphi method for expert consultation ensures the scientific and authoritative nature of the evaluation indicators. Research involves investigating the educational models of multiple engineering schools, analyzing the current status and challenges of fostering innovative ability, and refining evaluation indicators based on expert opinions. Ultimately, a set of evaluation scales applicable to engineering students' innovative ability is proposed, demonstrating its validity and reliability. The results indicate that this evaluation system effectively identifies and measures students' performance in various aspects of innovative ability, offering valuable insights for tailored innovation education in higher education institutions. This evaluation system not only enhances the overall quality of engineering students but also serves as a basis for educational policy development.

Keywords: Evaluation of Innovative Ability; Engineering Education; Delphi Method; Evaluation System; Educational Models

1. Introduction

1.1 Research Background

In the 21st century, innovation has become a crucial driver of global economic growth and social development. With the rapid rise of the knowledge economy and technological advancements, the enhancement of innovative ability has become increasingly crucial for improving national competitiveness. As the backbone in the field of future engineering technology, the cultivation of innovative ability among engineering students directly impacts the national level of technological innovation. In recent years, traditional engineering education models have faced significant challenges due to the emergence of Industry 4.0, artificial intelligence, and other technological revolutions, making it imperative to effectively enhance students' innovative ability as a focal point of higher education reform.

1.2 Research Objectives and Significance

This study aims to establish a scientific and systematic evaluation system for assessing the innovative ability of engineering students, providing theoretical guidance and practical references for higher education institutions. In educational practice, the cultivation of innovative ability is a continuous process, necessitating a scientific evaluation system for guidance and feedback. By defining evaluation indicators, educators can identify students' strengths and weaknesses in the innovation process, enabling targeted teaching improvements. Additionally, this research aims to promote innovation and transformation in engineering education models, supporting the enhancement of China's international competitiveness in engineering talent.

1.3 Review of Research Status at Home and Abroad

Internationally, research on students' innovative ability primarily focuses on constructing evaluation indicators and empirical analysis. The STEM education model in the United States emphasizes interdisciplinary comprehensive skill development, while Europe places more emphasis on the systematic and continuous nature of innovation education. Research on

the innovative ability of engineering students in China started relatively late but has made progress in recent years. Some scholars have proposed innovation capability cultivation models based on entrepreneurship education and attempted to align with international standards. However, current domestic research mostly remains at the theoretical exploration level, lacking systematic empirical research and mature evaluation systems.

2. Theoretical Basis

2.1 Overview of Innovative Ability

Innovative ability refers to an individual's comprehensive quality of proposing new ideas, methods, and products through creative thinking and practice based on knowledge accumulation. This ability involves not only a transformation in thinking but also requires individuals to possess analytical and problem-solving skills for complex issues. In the field of engineering, innovative ability is particularly crucial as technological advancements often rely on continuous updates and optimizations of technical solutions.

2.2 Characteristics of Engineering Education

Engineering education emphasizes a close integration of theory and practice. Compared to other disciplines, engineering courses emphasize the cultivation of hands-on practical skills and engineering thinking. With technological advancements, engineering education continuously incorporates knowledge from emerging disciplines, promoting disciplinary cross-linking and integration. Currently, the main challenge facing engineering education is how to maximize students' innovative potential with limited teaching resources. To address this challenge, many universities are exploring innovative teaching models such as project-based learning (PBL) and problem-based learning (PBL).

2.3 Theoretical Models of Innovative Ability Evaluation

Evaluating innovative ability involves multiple dimensions, including creative thinking, problem-solving skills, teamwork, technical application, and autonomous learning abilities. Constructing an evaluation model for innovative ability requires comprehensive consideration of these dimensions and determining their weights through scientific methods. The Delphi method, as a form of expert consultation, is commonly used to select evaluation indicators and determine their weights. In recent years, with the development of big data and artificial intelligence technologies, data-driven evaluation models have garnered attention, offering new possibilities for dynamic assessment of innovative ability.

3. Research Methods

3.1 Literature Review Method

The literature review method plays a crucial role in this study. By systematically searching, selecting, and analyzing relevant domestic and international literature on innovation capability and engineering education, the current research hotspots, trends, and deficiencies can be identified. Literature analysis not only helps researchers clarify theoretical frameworks but also provides necessary theoretical support for subsequent empirical studies. Combining research findings from both domestic and international sources, this study conducts in-depth analysis on aspects such as the definition, measurement methods, and key influencing factors of innovation capability, aiming to identify the most significant factors affecting innovation capability in engineering students. By repeatedly reading and organizing a large amount of literature, evaluation indicators and model construction methods suitable for the current research are extracted.

3.2 Delphi Method

The Delphi method is a research approach that systematically collects expert opinions through multiple rounds of feedback and revisions. By anonymously reducing direct influence among experts, this method enhances the objectivity and reliability of conclusions. In this study, 20 experts from universities, research institutions, and companies covering various fields such as education, engineering, and psychology were selected. Through three rounds of surveys, consensus was gradually reached to determine the core indicators of innovation capability in engineering students. Statistical analysis was conducted on the results of each survey round, which were then fed back to the experts for

revisions. The final evaluation indicator system to a certain extent reflects the current expectations of the education and industry sectors regarding innovation capability.

3.3 Data Collection and Analysis

The data collection stage involves two main aspects: quantitative data and qualitative data. Quantitative data mainly obtained through questionnaires involve self-assessment of students' innovation capability, evaluations from supervisors, and statistical analysis of actual innovation outputs. The questionnaire design, based on the indicator system determined through previous literature analysis and the Delphi method, was formally implemented after pre-survey and revisions. A total of 300 students from three grades of an engineering major at a certain university were selected as samples, achieving an 85% response rate. Qualitative data was collected through interviews and observations, primarily used to validate the accuracy of questionnaire results and gain a deeper understanding of students' innovation processes. Data analysis utilized SPSS and NVivo software, with quantitative data processed using descriptive statistics, factor analysis, and qualitative data refined through coding and thematic analysis to extract key viewpoints.

4. Construction of Evaluation Indicator System for Innovation Capability of Engineering Students

4.1 Selection of Evaluation Indicators

The selection of evaluation indicators directly impacts the scientific and effective assessment of innovation capability. Based on the results of literature analysis and the Delphi method, this study initially selected five primary indicators: creative thinking ability, problem-solving ability, technical application ability, teamwork ability, and self-directed learning ability. Each primary indicator was further refined into several secondary indicators. For example, creative thinking ability includes dimensions such as flexibility, originality, and critical thinking. Problem-solving ability encompasses problem identification, solution design, and implementation abilities.

4.2 Construction of Evaluation Framework

After determining the evaluation indicators, it is necessary to construct a systematic evaluation framework that not only covers all selected indicators but also clarifies the relationships between them. Combining the results of card sorting and expert interviews, the evaluation framework was structured using the Analytic Hierarchy Process (AHP) for presentation. The framework consists of four levels: overarching goal level, primary indicator level, secondary indicator level, and specific measurement item level. This structure facilitates a comprehensive and systematic evaluation of students' innovation capability and provides clear guidance for subsequent data analysis.

4.3 Determination of Indicator Weights

The determination of indicator weights is a crucial step in constructing the evaluation system. Weights reflect the relative importance of each indicator in the overall evaluation. Combining the results of the Analytic Hierarchy Process and the Delphi method, the method of consistency testing was used to determine the weights of each indicator. In the study, creative thinking ability and problem-solving ability were considered the two most important dimensions, with weights of 0.30 and 0.25, respectively. The weights of technical application ability, teamwork ability, and self-directed learning ability were relatively close, ranging from 0.15 to 0.20 each. To validate the rationality of the weights, the study tested students from different majors and grades, showing good consistency between weight distribution and students' actual innovation performance.

5. Empirical Research

5.1 Research Object and Sample Selection

This empirical study surveyed students majoring in engineering at a key domestic university as the research subjects. The reason for selecting this university is its high representativeness in engineering education, with top-quality educational resources and student quality in the country, which can provide real and effective data support for the research. The specific sample includes undergraduate students from the second to fourth year in the majors of Mechanical Engineering, Computer Science and Technology, and Electronic Information

Engineering, totaling 300 students. The sample selection took into account the differences in innovative abilities among different grades to comprehensively explore the changes in students' innovative abilities at different educational stages.

5.2 Data Analysis and Result Discussion

Data analysis was conducted using SPSS statistical software, revealing the impact of various indicators on students' innovative abilities through descriptive statistics, factor analysis, and regression analysis. The results indicated that creative thinking ability and problem-solving ability made the largest contributions to overall innovative ability, accounting for 35% and 30%, respectively. Technical application ability, teamwork ability, and self-directed learning ability accounted for 15%, 10%, and 10%, respectively. These data validate the hypotheses in theoretical analysis, that creative thinking is the core ability driving innovation, and problem-solving is an essential aspect of the innovation process.

Further analysis revealed significant differences in the performance of students from different majors and grades on various indicators. Students in Mechanical Engineering excelled in technical application ability, while Computer Science students had an advantage in creative thinking ability. Grade-level differences showed that senior students were more mature in teamwork and problem-solving abilities, reflecting the influence of educational stages on students' ability development.

5.3 Validation and Adjustment of Evaluation System

Based on the empirical research data, the validity and accuracy of the evaluation system were preliminarily confirmed. However, the measurement effects of some indicators still need further optimization. For example, the applicability of teamwork evaluation standards among different majors is insufficient and may require adjustments based on the characteristics of the majors. In addition, feedback from interviews indicated that the current indicator system lacks in reflecting students' innovation motivation and attitudes. Future considerations may include adding relevant behavioral observation indicators.

6. Conclusion

The study established an evaluation system for assessing the innovative abilities of engineering students, which was scientifically and operationally validated through empirical analysis. Creative thinking and problem-solving abilities were confirmed as core elements of innovative ability, with students from different majors and grades showing varying strengths and weaknesses in these abilities. The research results provide data support and theoretical basis for enhancing innovative ability cultivation in engineering education.

According to the research conclusions, universities should focus more on cultivating creative thinking in engineering education, encouraging students to engage in more interdisciplinary integration and project practices in their courses. Additionally, teachers can enhance students' problem-solving abilities by introducing practical engineering projects and open-ended topics. Schools should provide students with more innovation platforms and resources to support their growth in teamwork and self-directed learning.

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