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Analysis on Quality Evaluation of Higher Engineering Education from the Perspective of Outcome-based Education

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Abstract

The fourth industrial revolution brings new opportunities and challenges to the development of countries worldwide. As an important development power, engineering science and technology has become critical means for a country to stand out in the fierce international competition, the international engineering construction competition, and the core factor to improve the international right of speech. Higher engineering education is the main path for engineering science technological transfer and development. Hence, determining how to make a scientific evaluation of the comprehensive quality of higher engineering education, improve the higher engineering education quality, and train engineering innovative talents are keys to improving the comprehensive national competitiveness. Based on the outcome-based education (OBE) theory, studies concerning higher engineering education quality evaluation in the European and American developed countries were reviewed first. In this study, a comprehensive quality evaluation index system for higher engineering education was built through a survey of intelligent manufacturing and engineering education experts from 14 universities from applied science and engineering areas in Jiangsu Province of China. Moreover, the comprehensive quality of higher engineering education in these 14 universities was evaluated comprehensively using the AHP-TOPSIS method. Influencing factors of higher engineering education quality were ranked by using a barrier model. Results demonstrate that the established evaluation index system is operable. The judgment matrixes in the analytic hierarchy process (AHP) all pass the consistency check and the weight of teaching management is the highest (0.2950). The comprehensive engineering education quality ranking of universities is consistent with that of the third party. Teaching management is the first barrier factor in the barrier model and more attention has to be paid to disturbances of administration factors in universities against the improvement of higher engineering education quality. The obtained conclusions have very important values to updating the engineering education personnel training system, digital transformation, and improvement of engineering majors like intelligent manufacturing, as well as improving the innovation ability of engineering talents.

Keywords: OBE, higher engineering education, quality evaluation, TOPSI, AHP, obstacle-degree

1. Introduction

Technologies and industries centered on artificial intelligence (AI), mobile Internet, virtual reality (VR) and big data have prospered. Each industrial revolution has brought not only new development opportunities to global engineering scientific and technological development but also new opportunities and challenges to education development in countries around the world. Engineering science and technology are the direct driving forces of the progress of human civilization, the important power that has promoted the industrial revolution, economic development, and social progress, and even served as the bridge between scientific discoveries and industrial development. Higher engineering education is not only the main path for spreading and sublimation of engineering science and technology and the direct place to train high-quality engineering technicians, but also the creator of essential conditions for social progress and economic development. In the era of a global knowledge-driven economy, engineering technology plays an important role in solving complicated problems related to human lives. Engineering education has considerable influence in various fields of production and manufacturing in addition to bringing global economic development, thereby causing fundamental changes in the configuration of global production elements. In the field of higher education, the engineering education system has had the greatest effect from the scientific and technical revolution. Engineering education in countries is undergoing deep reforms continuously with the tide of new industrial revolutions. The whole world is facing the rapid transformation of engineering education mode while addressing sustainable development problems. Training high-quality technicians play an indispensable role in development. Many countries are developing engineering education modes with their national characteristics. Fig.1 shows that engineering education developed very quickly in China, manifested by annual growth in the number of engineering students and teachers. In the background of digital economic development, China has to focus on solving major problems in higher engineering education to become an innovative country. The key is to train excellent engineering talents and improve higher engineering education quality to realize harmonious development of

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comprehensiveness and practice innovation and get on the new road of industrialization.

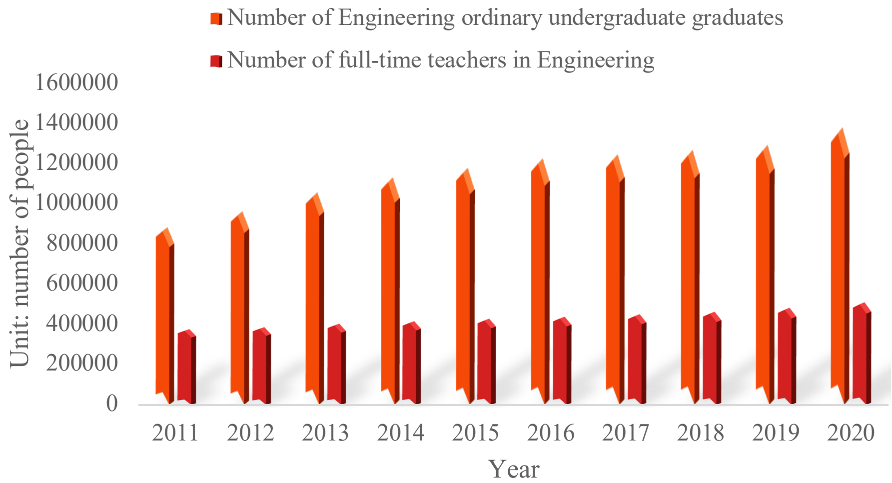

Fig.1 Quantity of engineering undergraduates and professional teachers in China

The outcome-based education (OBE) theory emphasizes attention to higher engineering education quality. It makes a comprehensive full-process evaluation by orienting to education outcomes, facilitating talent training quality improvement according to the evaluation results, and improving talent training quality continuously. The OBE theory optimizes course evaluation design and implementation by orienting to learning outcomes of students, developing the functions and effects of course evaluation fully, and improving the higher engineering education quality. The training system of engineering education, talent training structure, and training mode all have to be adjusted accordingly. Improving engineering education quality is conducive to the rapid development of economic construction and it is the key step to constructing an innovative country. Evaluating the higher engineering education quality, proposing evaluation subjects, indices and methods, analysis and feedback of evaluation results, and continuous improvement can perfect the evaluation theory of university engineering education quality and facilitate scientization of associated studies and the reasonable building of evaluation system. A scientific evaluation of higher engineering education quality must be based on the authentication idea of engineering education, build an evaluation system combining with characteristics of universities, promote relevant practices, and finally facilitate improvement of teaching quality and comprehensive quality of engineering professionals.

2. Literature Review

Spady [1] proposed the OBE theory in 1981. It views “learning outcome” as the core process, while education courses and structures are used as means rather than teaching objectives. Educators aim to help students realize these expected objectives when setting education objectives, and then design a scientific and reasonable education structure. They have to consider the ability and level that students should developed during the whole semester. Moreover, the power of the education system is not only from the experiences of teachers and doctrines in textbooks but also from the outcomes of students. These factors differ significantly from the driving force and inputs of traditional education. The OBE theory emphasizes the outcome of the teaching process. Course teaching shifts attention from course teaching to the training of students’ behaviors and ability so that students can obtain a good education. The OBE theory is extensively applied to various fields of countries. With the extensive applications of engineering technologies in modern productions, engineering connotations also change with age. As scientific and technological activities penetrate various social activities, it is inevitable to seek comprehensive engineering talents in modern society. Engineering education has become a major channel for engineering talent training. The higher engineering education in this study refers to the undergraduate program of engineering education, which is, setting engineering majors in universities. According to the meaning of education mode, the engineering education mode can be understood as the combination of a series of stable and continuous characteristics gained from the overall pattern analysis of engineering colleges in different historical stages and reflect internal education factors for research. Concerning the comprehensive quality evaluation of higher engineering education, Peercy et al. [2] updated the evaluation index system of engineering education quality and verified the scientificity of the system. Prados et al. [3] believed that American engineering education assured graduates of approved courses being prepared for professional practices and shall support the continuous improvement of the engineering education approval. Patil et al. [4] pointed out that approval and evaluation of academic courses are vital in engineering education to keep the quality and status of engineering graduates. He also briefly reviewed the existing approval system in global engineering education and described the method to develop a global approval model for engineering education. Gereffi et al. [5] carried out a comparative analysis of common statistical data of engineering graduates in America, China, and India and concluded that the key problem of engineering education lies in the quality rather than quantity of graduates because quality is the primary influencing factor of innovation and entrepreneurship. Sakthivel et al. [6] developed a tool to measure customers’ perceived quality of higher engineering education. An empirical test of a single dimension, reliability, and structural validity was carried out using the confirmatory factor analysis. This questionnaire can be used effectively in engineering colleges to improve education quality. Wulf et al. [7] believed that engineering education is facing reform and he suggested applying industrial quality control standards to engineering education, which could create more stimuli to students, increase more values, and complete more work in a shorter period. Mehta et al. [8] determined 13 principles for implementation of total quality management through the Delphi method and applied them to engineering education. Relations among these principles were established by interpretive structural modeling. They are conducive to determining the levels of actions adopted to improve engineering education quality. According to the results, more attention should be given to the principles with the higher driving force to improve engineering education quality comprehensively, such as quality mission and vision statement, senior management commitment, and visionary leadership. Berry et al. [9] described how engineering education offers the potential to improve the efficiency, effectiveness, and quality of contemporary teaching methods, and proposed a new curriculum integration mode to increase engineering education quality. Sakthivel et al. [10] believed that the principle of total quality management has been applied to higher education successfully in developed countries like USA and UK, and proved the necessity to develop a new excellent engineering education mode in India, which could be applied to engineering colleges effectively to improve their engineering education quality. Downey [11] pointed out that facing rapid technological reform, engineering education must recombine cores of engineering sciences and summarize three strategies to improve engineering education quality. Heitmann [12] deemed that engineering education must cope with a series of changing demands by encouraging diversity and innovative solutions, thus helping to strengthen engineering education. Mills et al. [13] demonstrated that an inclusive approach is not only conducive to the progress of students with social and cultural underrepresentation but also may expand the horizons of all students, thereby improving the overall quality of engineering projects. Calvo et al. [14] indicated that students' experiences with engineering teaching quality are directly related to overall satisfaction with the subject, while the period of schooling, class size, and professional development of coordinators are significantly correlated with the satisfaction and learning experiences of students. Natarajan [15] found complicated factors to improve engineering education quality. He introduced key elements of the Washington Accord and evaluated engineering education quality in universities in India [16]. Yasar et al. [17] discussed the professional engineering education of *Computational Science and Engineering* and believed that curricula, as well as contents of the curriculum and degree, have obvious influences on engineering education quality. Sthapak [18] believed that engineering education has supported India's development and different types of engineering companies have positive roles in the improvement of engineering education quality. Chen et al. [19] proved that the teaching mode of student teams plays an important role in the engineering education of software majors. Choudhury [20] evaluated 1178 engineering undergraduates in Delhi, India and showed that engineering colleges should shift attention from traditional teaching and student assessment methods to interactive learning approaches to improve technological education quality in India. Khan et al. [21] analyzed the appearance of online learning network technologies and tools and found that they have very important influences on engineering education. The proposed suggestions provide a roadmap for high-quality teaching and assessment of online engineering courses. Lakal et al. [22] discussed a focus group composed of 28 teachers from the India Engineering Research Institute and determined the specific engineering education dimension in the Indian environment. According to the results, the engineering education service quality model includes eight dimensions, including four (research direction, project opportunity, individual development, and high-order learning) having obvious influences on service quality improvement. Dawabsheh et al. [23] tested the influences of university facilities on engineering education quality in Malaysia and found significant positive correlations among engineering education quality, university facilities, teaching level, and professional development. Almetov et al. [24] demonstrated that engineering education content affects the formation and development of engineering creativity in students, and also has significant influences on the professional skills and self-development of future engineers. Takala et al. [25] pointed out that engineering education can improve the reflective thinking, creativity, innovation ability, and entrepreneurship of engineering undergraduates. Winberg et al. [26] discovered a mutual dependence between engineering knowledge and professional skills exists so that engineering graduates could gain professional ability. Duarte et al. [27] believed that engineering education quality should focus on promoting sustainable development of students and focus more attention to training criticism and morality of students. Nyka [28] argued that attention should be given to the combination of architectural concepts with environmental and water governance problems during teaching when improving engineering education quality for students who majored in environmental engineering. Malhotra et al. [29] demonstrated that multimedia presentation elements have obvious influences on engineering education quality and they help the engineering education system develop into a better platform. Elsafty et al. [30] suggested optimizing blended learning by taking advantage of traditional education and online education and proposed a technology that uses the CDIO method that can be used for top-level engineering education and improve the training quality of undergraduates in complicated, innovative, and research-based engineering activities. According to a review of higher engineering education transformation and development histories in typical foreign countries and typical foreign universities, the OBE theory emphasizes practical learning needs of learners, has explicit focus on expected learning outcome, and guarantees the realization of the expected learning outcome and training of students' ability by orienting to learning results. The OBE theory is an important theoretical basis of engineering education, and engineering education has been provided comprehensively in developed countries in the world as represented by USA, Germany, and Japan. Higher engineering education in China has long development history, has changed considerably, and is influenced by multiple factors. Generally, high-quality engineers have been trained very well. At present, China's higher engineering education has to learn the experiences of developed countries in engineering management and adjust and improve them according to practical situations in China. Specifically, it is important to make a scientific and reasonable evaluation of higher engineering education quality. The principal line for engineering education approval is centered on output, improving engineer training quality according to training objectives, making Chinese engineers match international requirements, and realizing China's engineering education objective is equivalent to the international objective.

3. Methodology

3.1 AHP-TOPSIS and Obstacle Degree model

In this study, it assumed that there were *m* objectives and *n* attributes. If the assessed value of experts to the j^{th} attribute of the i^{th} objective is x_{ij}, the initial judgment matrix (V) is expressed as Eq.(1):

$$V=\begin{bmatrix} x_{11} & x_{12} & \cdots & x_{1n} \\ x_{21} & x_{22} & \cdots & x_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x_{i1} & \cdots & x_{ij} & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ x_{m1} & x_{m2} & \cdots & x_{mn} \end{bmatrix} \tag{1}$$

However, because the indices might have different dimensions, it is necessary to normalize V to obtain V':

$$V'=\begin{bmatrix} x'_{11} & x'_{12} & \cdots & x'_{1n} \\ x'_{21} & x'_{22} & \cdots & x'_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x'_{i1} & \cdots & x'_{ij} & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ x'_{m1} & x'_{m2} & \cdots & x'_{mn} \end{bmatrix} \tag{2}$$

where x'_{ij} Eq. (2) is transformed by Eq. (3).

$$x'_{ij}=x_{ij}/\sqrt{\sum_{k=1}^{n}x_{ij}^{2}}\,(i=1,2,\cdots,m;j=1,2,\cdots,n) \tag{3}$$

Subsequently, the information weight matrix (B) of the expert group to attributes was acquired by the weights calculated by the analytic hierarchy process (AHP), forming the weighted judgment matrix (Z), as shown in Eq. (4).

$$Z=V'B=\begin{bmatrix} x'_{11} & x'_{12} & \cdots & x'_{1n} \\ x'_{21} & x'_{22} & \cdots & x'_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ x'_{i1} & \cdots & x'_{ij} & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ x'_{m1} & x'_{m2} & \cdots & x'_{mn} \end{bmatrix}\times\begin{bmatrix} w_1 & 0 & \cdots & 0 \\ 0 & w_2 & \cdots & 0 \\ \vdots & \vdots & \vdots & \vdots \\ 0 & \cdots & w_j & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ 0 & 0 & \cdots & w_n \end{bmatrix}=\begin{bmatrix} f_{11} & f_{12} & \cdots & f_{1n} \\ f_{21} & f_{22} & \cdots & f_{2n} \\ \vdots & \vdots & \vdots & \vdots \\ f_{i1} & \cdots & f_{ij} & \cdots \\ \vdots & \vdots & \vdots & \vdots \\ f_{m1} & f_{m2} & \cdots & f_{mn} \end{bmatrix} \tag{4}$$

The positive and negative ideal solutions to evaluation objectives were acquired according to a weighted judgment matrix (Eq. (5)):

$$f_j^*=\begin{cases}\max(f_{ij}), j\in J^* \\ \min(f_{ij}), j\in J'\end{cases} \qquad f_j'=\begin{cases}\min(f_{ij}), j\in J^* \\ \max(f_{ij}), j\in J'\end{cases} \tag{5}$$

where J^* is the efficiency index and J' is a cost index. The Euclidean distances between target values and ideal values were calculated as follows:

$$S_i^*=\sqrt{\sum_{j=1}^{m}(f_{ij}-f_j^*)^2}, j=1,2,...,n \qquad S_i'=\sqrt{\sum_{j=1}^{m}(f_{ij}-f_j')^2}, j=1,2,...,n \tag{6}$$

Finally, the relative degree of closeness of objectives was calculated.

$$C_i^*=S_i'/(S_i^*+S_i'), i=1,2,...,m \tag{7}$$

Based on the clustering of evaluation objects, key constraints against comprehensive engineering education quality in universities were explored using the barrier model. This step can improve comprehensive engineering education quality in different types of universities effectively and quickly by controlling and improving key factors. Moreover, specific countermeasures were formed. The research models are shown in Eqs. (8)–(10).

$$F_i=R_i\times W_i \tag{8}$$

$$I_i=1-X_i \tag{9}$$

$$Y_i=\frac{F_i\times I_i}{\sum_{i=1}^{m}F_i\times I_i}\times 100\% \tag{10}$$

where F_i is the contribution of factors, that is, the influence degree of the single index on the overall objective. I_i is the degree of index deviation, that is, the difference between the assessed value of an index and 100%. Y_i is the degree of barrier, that is, the influence degree of a single index on the overall objective. W_i is the weight of the j^{th} index. R_i is the weight of the class that the i^{th} index belongs to. X_i is the normalized value of a single index.

3.2 Data Source

Higher engineering education quality assessment has attracted increasing attention in China and foreign countries, and has become a topic that experts and scholars have explored further. It was found through a literature review that foreign experts are deepening their studies and understanding of teaching quality evaluation continuously. Research and applications of the OBE theory and teaching quality evaluation have been relatively mature. Based on

previous studies on higher engineering education quality evaluation systems and literature review, a questionnaire of *Comprehensive Quality of Higher Engineering Education from the Perspective of OBE* was designed.
The questionnaire was sent to 18 senior professors and 17 teaching management staff from 14 engineering universities in Jiangsu Province offline and online. The comprehensive quality evaluation index system of higher engineering education was formed after repeated communication and exchange (Table 1).

Table 1. Comprehensive quality evaluation indices of higher engineering education

Objective level	Level-1 indices	Level-2 indices
Comprehensive engineering education quality	Teaching document	Teaching program Instruction plan Teaching plan Textbook and teaching materials
	Teaching of teachers	Teaching content Teaching method Homework of students Tutorship and question answering Information feedback
	Learning of students	Project-based learning Group cooperative learning Midterm test Final examination
	Teaching management	Experimental apparatus Multimedia classroom Online learning Course supervision intensity Participation in quality evaluation

4. Results Analysis and Discussion

4.1 AHP Results

A total of 34 professors and teaching management staff from several universities in Jiangsu Province were invited for an online questionnaire survey. The weights of indices were calculated by AHP. Generally speaking, the judgment matrix has better consistency if CR is smaller. The judgment matrix meets the consistency check if CR is smaller than 0.1. Table 2 shows that all the judgment matrices passed the test.

Table 2. Consistency check

Indexes	Maximum eigenvalue	CI	RI	CR	Results
Comprehensive engineering education quality	4.186	0.062	0.89	0.07	PASS
Teaching documents	4.252	0.084	0.89	0.094	PASS
Teaching of teachers	5.312	0.078	1.12	0.07	PASS
Learning of students	4.118	0.039	0.89	0.044	PASS
Teaching management	5.336	0.084	1.12	0.075	PASS

Table 3. Weights of indices

Objective level	Level-1 indices	Weights of level-1 indices	Level-2 indices	Weights of level-2 indices	Total weight
Comprehensive engineering education quality	Teaching document	0.2117	Teaching program	0.2169	0.0459
			Instruction plan	0.2838	0.0601
			Teaching plan	0.2838	0.0601
			Textbook and teaching materials	0.2156	0.0456
	Teaching of teachers	0.2538	Teaching content	0.1663	0.0422
			Teaching method	0.2166	0.0550
			Homework of students	0.1639	0.0416
			Tutorship and question answering	0.1766	0.0448
			Information feedback	0.2766	0.0702
	Learning of students	0.2395	Project-based learning	0.1524	0.0365
			Group cooperative learning	0.2024	0.0485
			Midterm test	0.3298	0.0790
			Final examination	0.3155	0.0756
	Teaching management	0.2950	Experimental apparatus	0.1671	0.0493
			Multimedia classroom	0.1762	0.0520
			Online learning	0.2428	0.0716
			Course supervision intensity	0.1645	0.0485
			Participation in quality evaluation	0.2495	0.0736

Table 3 shows that the weight of teaching management is the highest (0.2950), followed by the teaching of teachers, learning of students, and teaching documents. Specifically, the weights of information feedback, midterm test, final examination, online learning, and participation in the quality evaluation were higher than 0.07. These five indices ranked in the top 5.

4.2 TOPSIS Ranking

Table 4 shows that the TOPSIS method has to identify the positive and negative ideal solutions of evaluation indices.

Next, distances (D+ and D-) of evaluation objects to the positive and negative ideal solutions were calculated, respectively. According to D+ and D-, evaluation objects were ranked by calculating their degrees of closeness to the optimal scheme. University 8, University 7, and University 2 ranked in the Top 3 because these universities were facing the international development trend in the future. As the main place for the transformation of higher engineering education, universities are faced with the effects of a series of emerging technologies means and they shall realize technological innovation gradually by seizing the technological opportunity. Moreover, universities have to adapt to the new requirements for the transformation of higher engineering education to make corresponding organizational innovations. Other universities should 1) increase the proportion of engineering practices in higher engineering education and implement the practice-oriented teaching reform, 2) build an interdisciplinary training system during transformation and use advanced technologies positively to enrich teaching content, 3) build an interdisciplinary training system and transform higher engineering education by orienting engineering practices to reflect the scientificity of engineering practices, and 4) verify and strengthen the effectiveness and feasibility of interdisciplinary courses by using engineering practice courses following the corresponding curriculum system despite interdisciplinary pursuit. Moreover, engineering practices are objective feedback on students' comprehension and application ability of higher engineering knowledge. Hence, universities should extend spatiotemporal dimensions of higher engineering education.

Table 4. Comprehensive quality evaluation results of higher engineering education courses

Item	D	D-	C	Rank
NO.1	3.480	3.671	0.513	5
NO.2	3.072	3.715	0.547	3
NO.3	4.131	2.799	0.404	14
NO.4	3.661	3.365	0.479	8
NO.5	3.757	3.851	0.506	6
NO.6	4.046	3.460	0.461	9
NO.7	2.985	4.114	0.580	2
NO.8	2.664	4.443	0.625	1
NO.9	4.010	2.829	0.414	13
NO.10	3.349	3.212	0.490	7
NO.11	3.776	2.666	0.414	12
NO.12	3.692	3.154	0.461	10
NO.13	3.333	3.685	0.525	4
NO.14	4.010	3.225	0.446	11

4.3 Degree of Barriers

Table 5 shows the following:

(1) Teaching management is the first barrier against eight universities. This conclusion fully demonstrates that more attention should be given to administrative factors of teaching management in universities to improve the comprehensive quality of higher engineering education in China. This finding is mainly because of the contradiction between administrative power and academic power, especially administrative power over academic power, which is the primary problem in university management. Government sectors intervene in the autonomy of running universities. These factors disturb the internal logic and natural tendency of organization, governance, and operation of universities. Combined with the attributes of modern universities as multivariate institutions, university management should change from the traditional governance theory into multielement governance. It is also the theoretical basis for higher engineering education transformation. Concerning the current path choice of higher engineering education in China, the university is the consequence of multi-party coordination in terms of organizational management and institution setting. The transformation from traditional university governance to multielement governance is the basis and key to the transformation of higher engineering education. The transformation of higher engineering education involves changes in teaching mode, operation philosophy, and administrative organization. The interest subject of the university will also be influenced significantly. These influences run through the entire operation process of universities. Hence, it is necessary to improve the quality of higher engineering education through a comprehensive reform of the teaching management system.

Table 5. Degree of barriers against higher engineering education quality in 14 universities

Item	Teaching document	Teaching of teachers	Learning of students	Teaching management
NO.1	0.0868	0.3208	0.3561	0.2363
NO.2	0.281	0.1828	0.2467	0.2896
NO.3	0.1665	0.2182	0.282	0.3333
NO.4	0.2506	0.193	0.2242	0.3322
NO.5	0.2524	0.3027	0.1391	0.3059
NO.6	0.2563	0.1712	0.3365	0.2361
NO.7	0.1989	0.3578	0.1905	0.2529
NO.8	0.1672	0.1525	0.3331	0.3473
NO.9	0.3952	0.1965	0.2665	0.1417
NO.10	0.294	0.3653	0.2205	0.1203
NO.11	0.2006	0.3107	0.099	0.3897
NO.12	0.1265	0.1575	0.1951	0.5209
NO.13	0.2202	0.214	0.0622	0.5036
NO.14	0.1214	0.3076	0.3013	0.2697

(2) Teaching of teachers and learning of students are the second and third principal barriers because higher engineering education relies more on teachers in universities. China's higher engineering education was in the exploration stage around 2000. China has been exploring teaching modes and teaching levels continuously. Macroscopically, a training system of higher engineering education with rich levels and diversified specifications was formed. Higher education institutions in China obtained advanced experiences in the world and implemented fundamental reforms in the educational system, educational philosophy, teaching mode, and courses in engineering schools, thereby improving the teaching level and talent quality of engineering universities to some extent. Teachers should seize such advantages and establish a teaching mode based on the "Internet+" through technological innovation. They should also face learning and abandon traditional cultures accurately by combining the responsibilities of universities in social services and cultural inheritance, cope with cultural shock and adhere to its cultural inheritance. These factors are important teaching measures for teachers in higher engineering education. The learning of students is also a major factor because students are the objects of higher engineering education. The student-centered operation runs through the development of higher engineering education. It is suggested that students be given full respect, train their vocational interests, help students in exploring life and career planning and development, andist them in growing from engineering practitioners to engineering explorers. Additionally, higher engineering education also can attract good students through the college entrance examination. The top-class academic atmosphere in high-quality universities gives students the possibility to accept good engineering

practices. Through these measures, students can have a broader thinking mode and independent thinking habits. It is the prerequisite of students' practices and students can achieve continuous innovation and evolution of high-tech technologies by developing a spirit of exploration. Industrial development in the future needs more talents with learning ability and innovative thinking.

(3) Teaching documents are the major barrier to the improvement of higher engineering education quality. In other words, teaching documents for higher engineering education in China have become relatively standard after education approval over the years. At present, most course outlines of higher engineering education have formulated program objectives, teaching content and teaching method, course assessment mode and content, assessment and scoring criteria, and so on. The learning outcomes of students in the evaluation system are the reference for course quality assessment. Learning outcomes also contain examination scores of students and self-evaluation results of students based on their course goal achievement, including course examination, test, course report, experiment, homework, and performances in various assessment modes. Performances of the practice course include design reports, staged examination, drawings, instructions, thesis defense, and so on. These materials for higher engineering education approval are particular standards in most universities. Next, more attention should be given to online storage and real-time acquisition of teaching documents in the background of "Internet + education" can be realized for the convenience of teachers in teaching activities and teaching evaluation.

4.4 Discussion

Foreign engineering education is relatively mature and enjoys a very high reputation internationally. Thus far, most countries are reforming their higher engineering education continuously. Engineering education mode has become increasingly important in the new engineering background of China. Universities propose urgent demands for engineering talents, which facilitate engineering education in Chinese universities to obtain foreign experiences, further study foreign modes to assure better integration with China's practical situation, and promote the rapid development of engineering education in China. Engineering education mode is composed of the following elements: talent training objective, curriculum system, and teaching method. Given engineering education reform practices, there is no mutual influence among these elements. Instead, these elements facilitate and develop mutually. Hence, they form the main structural framework of engineering education mode together. The weights of indices concerning the comprehensive quality of higher engineering education can be acquired rapidly through the AHP-TOPSIS method. Universities that provide higher engineering education were ranked. The influencing factors of comprehensive quality evaluation of higher engineering education were classified and analyzed by the barrier model. From the perspective of OBE, the core of improving the comprehensive quality of higher engineering education lies in the course quality assurance system. It focuses on the learning outcome of students. The curriculum quality evaluation system should include various factors that influence the learning outcome of students with the aim of proposing specific measures for continuous improvement of higher engineering education quality.

5. Conclusion

Based on the OBE theory, a questionnaire survey of 34 engineering education experts from 14 engineering universities in Jiangsu Province is carried out and an evaluation index system of higher engineering education quality established. Weights of the evaluation indices are calculated using the AHP-TOPSIS method and specific barriers are calculated through the barrier model. Some major conclusions can be drawn. (1) "Fruit-orientation" is the core philosophy of engineering education. Among evaluation indices of higher engineering education quality based on the OBE theory, teaching management has the highest weight (0.2950). (2) The university engineering education quality ranking based on AHP-TOPSIS is consistent with the ranking formed by the third party. (3) Teaching management is the principal barrier to engineering education quality in universities. Hence, improving higher engineering education quality is the most critical measure to reform the engineering education management system in universities. Because this study focuses on universities in Jiangsu Province which has relatively advanced higher engineering education, the research objects and research conclusions might have some regional characteristics, without adequate consideration of education status in regions with underdeveloped engineering education. Hence, the research object range should be expanded further to include process factors, such as integrating engineering educational teaching activities into the comprehensive quality evaluation system, and further discussing the requirements of new technologies and new industrial development for engineering education talents.

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References

1. Spady, W. G. "*Outcome-Based Education: Critical Issues and Answers*", American Association of School Administrators, Arlington, VA. 1994..
2. Peercy, P. S., Cramer, S. M. "Redefining quality in engineering education through hybrid instruction", *Journal of Engineering Education*, 100(4), 2011, pp. 625-629.
3. Prados, J. W., Peterson, G. D., Lattuca, L. R. "Quality assurance of engineering education through accreditation: The impact of Engineering Criteria 2000 and its global influence", *Journal of Engineering Education*, 94(1), 2005, pp. 165-184.
4. Patil, A., Codner, G. "Accreditation of engineering education: review, observations and proposal for global accreditation", *European Journal of Engineering Education*, 32(6), 2007, pp. 639-651.

5. Gereffi, G., Wadhwa, V., Rissing, B., Ong, R. “Getting the numbers right: International engineering education in the United States, China, and India”, *Journal of Engineering Education*, 97(1), 2008, pp. 13-25.
6. Sakthivel, P. B., Raju, R. “An instrument for measuring engineering education quality from students’ perspective”, *Quality Management Journal*, 13(3), 2006, pp. 23-34.
7. Wulf, W. A., Fisher, G. M. “A makeover for engineering education”, *Issues in Science and Technology*, 18(3), 2002, pp. 35-39.
8. Mehta, N., Verma, P., Seth, N. “Total quality management implementation in engineering education in India: An interpretive structural modelling approach”, *Total Quality Management & Business Excellence*, 25(1-2), 2014, pp. 124-140.
9. Berry, F. C., DiPiazza, P. S., Sauer, S. L. “The future of electrical and computer engineering education”, *IEEE Transactions on Education*, 46(4), 2003, pp. 467-476.
10. Sakthivel, P. B., Raju, R. “Conceptualizing total quality management in engineering education and developing a TQM educational excellence model”, *Total Quality Management & Business Excellence*, 17(7), 2006, pp. 913-934.
11. Downey, G. “Are engineers losing control of technology? From ‘problem solving’ to ‘problem definition and solution’ in engineering education”, *Chemical Engineering Research and Design*, 83(6), 2005, pp. 583-595.
12. Heitmann, G. “Challenges of engineering education and curriculum development in the context of the Bologna process”, *European Journal of Engineering Education*, 30(4), 2005, pp. 447-458.
13. Mills, J., Ayre, M. “Implementing an inclusive curriculum for women in engineering education”, *Journal of Professional Issues in Engineering Education and Practice*, 129(4), 2003, pp. 203-210.
14. Calvo, R. A., Markauskaite, L., Trigwell, K. “Factors affecting students’ experiences and satisfaction about teaching quality in engineering”, *Australasian Journal of Engineering Education*, 16(2), 2010, pp. 139-148.
15. Natarajan, R. “The role of accreditation in promoting quality assurance of technical education”, *International Journal of Engineering Education*, 16(2), 2000, pp. 85-96.
16. Godfrey, E., Aubrey, T., King, R. “Who leaves and who stays? Retention and attrition in engineering education”, *Engineering Education*, 5(2), 2010, pp. 26-40.
17. Yasar, O., Landau, R. H. “Elements of computational science and engineering education”, *SIAM Review*, 45(4), 2003, pp.787-805.
18. Sthapak, B. K. “Globalisation of Indian engineering education through the Washington Accord”, *Journal of Engineering, Science & Management Education*, 5(2), 2012, pp. 464-466.
19. Chen, C. Y., Chong, P. P. “Software engineering education: A study on conducting collaborative senior project development”, *Journal of Systems and Software*, 84(3), 2011, pp. 479-491.
20. Choudhury, P. K. “Student assessment of quality of engineering education in India: Evidence from a field survey”, *Quality Assurance in Education*. 27(1), 2019, pp. 103-126.
21. Khan, Z. H., Abid, M. I. “Distance learning in engineering education: Challenges and opportunities during COVID-19 pandemic crisis in Pakistan”, *The International Journal of Electrical Engineering & Education*, 2021, pp. 0020720920988493.
22. Lakal, N., Joshi, K., Jain, K. “Development of engineering education service quality model from faculty perspective”, *Total Quality Management & Business Excellence*, 31(13-14), 2020, pp. 1442-1453.
23. Dawabsheh, M., Mustanir, K., Jermsittiparsert, K. “School facilities as a potential predictor of engineering education quality: Mediating role of teaching proficiency and professional development”, *TEST Engineering & Management*, 82(3511), 2020, pp. 3511-3521.
24. Almetov, N., Zhorabekova, A., Sagdullayev, I., Abilhairova, Z., Tulenova, K. “Engineering education: Problems of modernization in the context of a competence approach”, *International Journal of Engineering Pedagogy*, 10(6), 2020, pp. 7-20.
25. Takala, A., Korhonen-Yrjänheikki, K. “A decade of Finnish engineering education for sustainable development”, *International Journal of Sustainability in Higher Education*, 20(1), 2019, pp. 170-186
26. Winberg, C., Bramhall, M., Greenfield, D., Johnson, P., Rowlett, P., Lewis, O., Waldock, J., Wolff, K. “Developing employability in engineering education: A systematic review of the literature”, *European Journal of Engineering Education*, 45(2), 2020, pp. 165-180.
27. Duarte, A. J., Malheiro, B., Arnó, E., Perat, I., Silva, M. F., Fuentes-Durá, P., Guedes, P., Ferreira, P. “Engineering education for sustainable development: The European project semester approach”, *IEEE Transactions on Education*, 63(2), 2019, pp. 108-117.
28. Nyka, L. “Bridging the gap between architectural and environmental engineering education in the context of climate change”, *World Transactions on Engineering and Technology Education*, 17, 2019, pp. 204-209.
29. Malhotra, R., Verma, N. “An impact of using multimedia presentations on engineering education”, *Procedia Computer Science*, 172, 2020, pp. 71-76.
30. Elsafty, A., Sayad, H. E., Shaaban, I. “A business analysis perspective for engineering education in Egypt”, *Journal of Education and Training Studies*, 8(5), 2020, pp. 30-42.