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Abstract

The program accreditation of engineering education has globally become the main model of quality assurance in higher engineering education. In essence, the program accreditation of engineering education is an external mechanism for the quality assurance in higher engineering education. Under the guidance of external quality assurance mechanism, colleges and universities within different countries and regions actively explore the practice of quality assurance in engineering education, and promote all stakeholders to pay more attention to the practice and theoretical research of internal quality assurance in higher engineering education. Thus, this study firstly combines the research results of domestic and foreign scholars on the quality assurance mechanisms of higher education, and gives the definition and analyzes the fundamental connotation of the internal quality assurance mechanisms of higher engineering education. Secondly, it examines the internal quality assurance mechanisms of higher engineering education based on Total Quality Management Theory, Outcome-based Education Theory, Educational Mechanism Theory and Stakeholder Theory. Finally, it tries to construct the logical model of the internal quality assurance mechanisms of higher engineering education, hoping for providing an explanatory framework for the internal quality assurance in higher engineering education.

Keywords: Engineering Education Quality Assurance Program Accreditation Continuous Quality Improvement Mechanism

1. Introduction

Improving the quality of engineering education has become common concern for the global engineering education community, industry and business sectors. The quality assurance in engineering education is a systematic project, facing a special internal and external policy environment. At present, engineering education accreditation has become the main quality assurance mechanism for higher engineering education, and has promoted the formation of two major engineering education accreditation systems: Washington Accord (WA) and European Network for Accreditation of Engineering Education (ENAEE). The global engineering education accreditation presents the result-oriented, international connection, continuous improvement and industry-university cooperation trend [1]. Under this framework, colleges and universities in various countries and regions have tried to explore the path of quality assurance in engineering education at the theoretical and practical levels. However, existing research lacks scientific and rational thinking and is often reduced to a summary of practical experience.

The quality improvement of higher engineering education depends on the accreditation of accreditation agencies, the program evaluation of institutional accreditation, and the internal quality assurance of academic institutions. Among them, colleges and universities have always been the most important subject of quality improvement. Does the internal quality assurance mechanism of higher engineering education also include two forms? One is a
self-evaluation mechanism established to respond to external evaluations, and the other is an evaluation mechanism established to facilitate daily management and promote continuous quality improvement. Thus, it is urgently needed to explore the following specific issues in depth. First of all, how do colleges and universities carry out internal education quality assurance when they actively participate in the accreditation process? Secondly, in addition to dealing with program accreditation, do universities establish a normal quality assurance system of engineering education? How effective is its operation? Finally, as three core quality assurance entities, how do administrators, faculty and students play their roles?

The study firstly combines the current research on the quality assurance mechanism of higher education, defines the internal quality assurance mechanism of higher engineering education, and analyzes the fundamental connotation of the internal quality assurance mechanism of higher engineering education; secondly, tries to explore the internal quality assurance in higher engineering education, seeking the theoretical basis for the internal quality assurance mechanism of higher engineering education, from the perspectives of Total Quality Management Theory, Outcome-based Education Theory, Educational Mechanism Theory and Stakeholder Theory; thirdly, tries to construct a logical model of the internal quality assurance mechanism of higher engineering education; finally, analyzes the characteristics of quality assurance of colleges and universities participating the accreditation of American Accreditation Board for Engineering and Technology.

2. The Fundamental Connotation of the Internal Quality Assurance Mechanism of Higher Engineering Education

2.1 Definition

At present, there is no clear definition of “internal quality assurance mechanism of engineering education”. The academic circles have conducted discussion around the “quality assurance mechanism of higher education”, either on the external quality assurance mechanism of higher education, or on the internal quality mechanism of higher education, or on a certain quality assurance mechanism. For example, Louise Morley explored the relationship between quality and power, and investigated the power relationship in organizing and promoting quality assurance in higher education [2]. Morley’s research case is mainly micro-level research on quality assurance mechanism.

Generally speaking, the quality assurance in higher education is a practical activity in which stakeholders express and strive to realize their educational benefits and quality requirements by controlling educational resources. Due to the existence of diversified stakeholders, their value orientation and quality requirements are different, and conflicts between stakeholders are inevitable. Based on the research on quality assurance mechanism of higher education, this research attempts to define the concept of “internal quality assurance mechanism of engineering education”, that is a set of systematic thinking and action logic for the management of engineering education, on the basis for universities to analyze the quality requirements of stakeholders in engineering education, based on specific quality management theory, using specific quality management methods. In essence, it is a highly generalization including stakeholder, organization, policy, system, philosophy, procedure and technology of
quality assurance in engineering education.

In order to ensure the scientificity of the definition, it is necessary to further limit the application scope. First, “engineering education” in this research mainly focuses on higher engineering education. Secondly, “internal quality assurance” mainly focuses on the quality assurance in engineering education at the program level.

2.2 Connotation

From the perspective of etymology, the term “mechanism” originated from the Greek word “mechane”, which refers to the structure and working principle of machinery. From a disciplinary perspective, “mechanism” is mostly used in natural science, and it is also used in social science. The application of “mechanism” in social science began in the late 1940s. Specifically, the dimensions of “mechanism” in social science include the structure, function, formation establishment form and carrier of the mechanism [3]. Regarding the formation of mechanism, there are two viewpoints, i.e. historical evolutionism and constructivism. According to the internal quality assurance practice carried out by colleges and universities to meet the program accreditation requirements, the perspective of constructivism seems to be more explanatory. However, in a sense, the perspectives of constructivism and historical evolutionism are not completely conflicting. In the historical evolution process of the internal quality assurance of engineering education, it also contains the development logic of constructivism. It is because of the continuous appeal for the perfection of mechanism that the quality assurance mechanism has gradually matured and become normalized.

(1) The evolution and development of the internal quality assurance mechanism of higher engineering education

Historical evolutionism believes that mechanism has a strong path dependence which is the result of long-term historical evolution. The understanding of the mechanism of historical evolutionism implies two logics. First, the mechanism itself has undergone a long-term evolution process, gradually changing from immaturity to maturity and from abnormality to normalization. Correspondingly, the process of forming the internal quality assurance mechanism of engineering education is divided into stages of immaturity and maturity, abnormality and normalization. When examining the connotation of the internal quality assurance mechanism of engineering education, it is necessary to distinguish and explain the stages of its formation and development. Secondly, no matter what evolution process the mechanism itself undergoes, some key elements are involved, which constitute the basis for the continuous operation of the mechanism. When investigating the connotation of the internal quality assurance mechanism of engineering education, it is necessary to focus on the key elements of its formation and development. The evolution logic of the internal quality assurance of engineering education in colleges and universities integrates the institutional environment factors of engineering education program accreditation, science education and management movement. Science education and management movement is the fundamental driving force to promote the normalization of the internal quality assurance mechanism of
engineering education. Under the science education and management movement, quality assurance concept, quality assurance subject, quality assurance technology, and quality assurance management have been formed. These all constitute the key elements of the normal mechanism of quality assurance in engineering education.

(2) The construction and generation of the internal quality assurance mechanism of higher engineering education

Constructivism believes that the mechanism to achieve established social goals can be designed. Constructivism focuses on the influence of external factors on the results of the mechanism, and emphasizes human initiative. As far as the internal quality assurance in engineering education is concerned, due to its institutional environment——program accreditation of engineering education, it is necessary to establish and improve a response mechanism to meet the social goal of program accreditation. This response mechanism is a adjustment made by universities and programs on the basis of an accurate grasp of the quality assurance mechanism, as a supplement to the traditional quality assurance mechanism. To investigate the internal quality assurance in engineering education from the perspective of constructivism is to dynamically present the changes and reforms of internal mechanism. Similarly, Constructivism’s understanding of the mechanism also implies two logics. First, the mechanism itself can be designed to breed new mechanisms. When investigating the connotation of the internal quality assurance mechanism of engineering education, it is necessary to explain the structure principle, operation rules of mechanism. Secondly, the formation of mechanism needs to fully consider the influence of external environmental factors and the initiative of internal actors. When examining the connotation of the internal quality assurance mechanism of engineering education, it is necessary to consider not only the program accreditation of engineering education, but also the initiative value of the internal actors. Program accreditation of engineering education is the external driving force leading the quality assurance in engineering education. Therefore, the internal quality assurance mechanism is changed in accordance with the adjustment of the program accreditation mechanism of engineering education. This change may be an overall change, or it may be a local adjustment.

3. Theoretical Investigation of the Internal Quality Assurance Mechanism of Higher Engineering Education

Based on the perspectives of total quality management theory, output-oriented education theory, education mechanism theory, and stakeholder theory, this part further conducts a multi-angle theoretical investigation of the internal quality assurance of engineering education in colleges and universities, and discusses related theories and internal quality assurance of engineering education The relationship provides theoretical legitimacy for the analysis framework of the internal quality assurance mechanism of engineering education in colleges and universities.

3.1 The internal quality assurance in higher engineering education from the perspective of Total Quality Management Theory
(1) Total Quality Management Theory

The Total Quality Management Theory (TQM) was first proposed by Armand Vallin Feigenbaum in the United States in the early 1960s. In 1961, Feigenbaum first proposed the concept of TQM. Since then, Feigenbaum’s TQM view has been widely used and worldwide accepted, its concept and connotation have also been further developed. At present, the academic circles generally definite TQM as follow, i.e. an organization takes quality as the core and is based on full participation to achieve long-term success by satisfying customers and benefiting all stakeholders of the organization and the society.

(2) Enlightenment to the theory and practice of quality assurance in engineering education

As we all know, higher education is a systematic and complex educational activity, with essential characteristics different from industrial and commercial activities. There are obvious contradictions and conflicts between higher education management and TQM’s benefit-oriented value foundation and hypothesis of economic man. TQM in the industrial and commercial industry pursues efficiency instead of human development. However, TQM has a certain influence on many aspects of higher education management. Since entering the 21st century, TQM is still playing a role in the quality assurance in higher education. The comprehensiveness, full participation, and full process advocated by TQM are embodied in the quality assurance in higher education. Since the 1990s, the concept of quality has frequently appeared in the engineering education, and the principles of quality assurance have also begun to be introduced into the engineering education research. Relevant research began to investigate the quality concept and quality assurance concept of engineering education, and tried to introduce related concepts of quality assurance into engineering education research [4] [5]. The continuous improvement of engineering education conforms to the quality assurance theory of PDCA [6]. Therefore, the whole-process and all-round quality evaluation concepts advocated by TQM are consistent with the direction of quality assurance in engineering education.

In this research, the quality assurance mechanism of engineering education is a continuously improved, well-organized, and fully-participated mechanism. Its effective operation must be based on a specific methodology and rely on specific quality management ideas and methods. Continuous quality improvement (CQI) is such an idea developed from TQM, refers to a specific deliberate process that can optimize the quality outcome of a system [7]. The application of CQI in the engineering education is reflected in two levels, i.e. institutional accreditation and program accreditation. First of all, the CQI concept continues to shape and condense accreditation culture, influence and internalize the thoughts and behaviors from the leaders to the general members. Secondly, the CQI concept guides the development of accreditation activities and the formation of self-assessment culture. The continuous quality improvement of institutes is synchronized with the one of accreditation agencies. Only when institutes form a CQI concept based on self-assessment can the CQI concept of accreditation agencies be realized.
3.2 The internal quality assurance in higher engineering education from the perspective of Outcome-based Education Theory

(1) Outcome-based Education

Outcome-based Education (OBE) has become the mainstream concept of educational reform in many countries. In 1981, Spady W. D. took the lead in proposing the concept of OBE. Subsequently, OBE gained attention and application at an astonishing speed. Spady conducts an in-depth study of this model, and believes that OBE can “clearly focus and organize the education system to ensure that students gain substantial success in future life” [8]. He believes that OBE is a structural model that organizes implements and evaluates education centered on expected learning outcome, realizing the transformation of educational paradigm.

(2) Enlightenment to the theory and practice of quality assurance in engineering education

Although there is still controversy in the academic circles as to whether OBE can be called a “theory”, the practicality of OBE has already shown an irresistible trend. Under the influence of OBE, the outcome-based assessment concept is deeply rooted in the hearts of the people, and the reform of engineering education and teaching continues to deepen. In the research of quality assurance in engineering education, many outcome-based assessment concepts and methods have also emerged. When analyzing the continuous improvement mechanism of quality assurance in engineering education, OBE is an important theoretical basis.

3.3 Internal quality assurance in higher engineering education from the perspective of Educational Mechanism Theory

(1) Educational Mechanism Theory

The Educational Mechanism Theory is an educational management theory proposed and advocated by Prof. Miantao Sun. He believes that “educational mechanism is the interrelationship between the various components of the educational phenomenon and the way in which they operate.” [9] Educational mechanism includes three major categories, i.e. hierarchical mechanism, formal mechanism and functional mechanism. The hierarchical mechanisms include macro-mechanism, meso-mechanism and micro-mechanism. Formal mechanisms include administrative mechanism, guidance mechanism, and service mechanism. Functional mechanisms include incentive mechanism, restriction mechanism and guarantee mechanism. Compared with other theories, the Educational Mechanism Theory points out how to operate the educational mechanism.

(2) Enlightenment to the theory and practice of quality assurance in engineering education

According to Educational Mechanism Theory, the internal quality assurance mechanism of engineering education can be interpreted from the three dimensions, i.e. hierarchical mechanism, formal mechanism, and functional mechanism. First of all, to examine the
internal quality assurance mechanism of engineering education from the hierarchical perspective is to clarify the relationship between the relevant organizations and their operating methods. Secondly, to examine the internal quality assurance mechanism of engineering education from the formal perspective is to clarify the relationship between the subject and object of quality management and how they operate. Finally, to examine the internal quality assurance mechanism of engineering education from the functional perspective is to examine the relationship between relevant policies and system assurance elements and how they operate, which is reflected in the incentive mechanism, restriction mechanism, and guarantee mechanism.

3.4 Internal quality assurance in higher engineering education from the perspective of Stakeholder Theory

(1) Stakeholder Theory

The Stakeholder Theory is an important concept put forward by R. Edward Freeman in 1984. Since the 1980s, with the development of economic globalization and the intensification of competition among enterprises, issues such as corporate governance and corporate social responsibility have become the focus of attention and discussion. The Stakeholder Theory advocates that all stakeholders affected by the enterprise interests have the right to participate in corporate decision-making. Freeman proposed that stakeholders are all individuals and groups that can influence the realization of an organization’s goals, or are affected by the process of realizing its goals [10]. Stakeholders and their participation are of great value to the achievement of organizational goals.

(2) Enlightenment to the theory and practice of quality assurance in engineering education

After Stakeholder Theory was introduced into the theoretical research of higher education, it is mainly used as an important analytical framework. It is very important to clarify the main stakeholders of higher education and their roles. Before proposing any quality improvement measures, the decision-making department should first conduct a stakeholder analysis. Due to the variety of stakeholders involved in the quality assurance in higher education, there are also many different ways of dividing. For example, Mitchell R. K. and others analyzed stakeholders based on power, legitimacy and urgency. “Power” refers to the participant’s ability to exert influence in various relationships; “legitimacy” refers to the extent to which the participant’s behavior is desirable, correct and appropriate; “urgency” refers to the degree of urgency with which the participant’s claim has been noticed. Maassen believes that stakeholders have become more and more important and have a greater impact on the internal affairs of higher education [11]. Campbell and Rozsnyai believe that the stakeholders of higher education quality include students, society and the government [12]. Jongbloed Ben and others applied the stakeholder concept developed by Mitchell and others to higher education to explain the attention paid to various stakeholders and their relationship with the university [13]. In recent years, the student power has begun to return, and a power relationship has gradually formed that balances with the academic power and the
There are three interdependent, mutually-promoting, and mutually restrictive power groups in the internal quality assurance system of colleges and universities, namely administrative power, academic power and student power. The internal quality assurance of universities involves various interest-related groups, and there are also several powers composed of these interest groups. After the stakeholder theoretical perspective was introduced into higher education, there have also been some researches on the quality assurance in engineering education based on the stakeholder theoretical perspective. For example, the research on stakeholders and their roles in accreditation process [14], the evaluation culture of stakeholders in accreditation process [15], and the stakeholders analysis in the engineering education system [16]. The stakeholders involved in the quality assurance in engineering education are more complex and specific. With the assistance of Stakeholder Theory, by studying the power allocation, types and ways of power participation in the quality assurance in higher engineering education by different power bodies, it helps to understand the internal quality assurance mechanism of higher engineering education.

4. The Model Construction of the Internal Quality Assurance Mechanism of Higher Engineering Education

According to the connotation of the internal quality assurance mechanism of higher engineering education based on historical evolutionism and constructivism, this research found that the interpretation of the internal quality assurance mechanism of higher engineering education needs three important types of mechanisms: stakeholder participation, institution coordination, and continuous improvement. Through the theoretical investigation on the internal quality assurance in higher engineering education, we have found the theoretical sources of the dimensions of technology, management and power respectively. On the basis of these three dimensions, this research has further formed an analysis framework for the internal quality assurance mechanism of higher engineering education.

4.1 The framework and elements of the internal quality assurance mechanism of engineering education

(1) Stakeholder participation mechanisms

The internal quality assurance in engineering education involves various stakeholders, and there are also several powers composed of these interest groups. Various powers constantly engage in value games in order to realize their own value demands. The internal quality assurance in engineering education involves three main powers, i.e. administrative power, academic power and student power. Different powers play different roles and functions in the internal quality assurance process of engineering education types and forms of participation embodied by different power subjects.

(2) Institution coordination mechanisms
The internal quality assurance in engineering education is a comprehensive and systematic project. Specifically, hierarchical, functional and formal institutions constitute the institution coordination mechanism of internal quality assurance in engineering education. There is a close logical relationship between the various mechanisms and their elements. The “hierarchical institution” refers to the investigation on the way of operation from the hierarchical perspective; the “functional institution” refers to the investigation on the operating methods from the functional perspective; the “formal institution” refers to the investigation on the development methods from the formal perspective, and the interrelationship of various elements contained in the internal quality assurance in engineering education.

(3) Continuous improvement mechanisms

The core concept of quality assurance in engineering education in colleges and universities is continuous quality improvement. Continuous quality improvement is a specific requirement of program accreditation agency, and gradually promotes the formation of mechanisms for continuous improvement of the engineering education quality. Through the continuous improvement mechanism, the philosophy of continuous quality improvement is gradually internalized into the quality assurance in engineering education. To examine the internal quality assurance mechanism of engineering education from the technical perspective is to clarify how engineering education is achieved through continuous quality improvement, how to build technical models, and how to implement complex procedures for technical operations, in order to improve the quality of engineering education.

4.2 The logical model of the internal quality assurance mechanism of engineering education

Through the aforementioned theoretical analysis, we have gradually clarified the connotation and dimensions of the internal quality assurance mechanism of higher engineering education. On this basis, it still needs to further build a logical model of the internal quality assurance mechanism of engineering education in order to better interpret the operating mechanism of the internal mechanism. It is not difficult to find that no matter what changes occur in the internal and external environment of colleges and universities, the practice of internal quality assurance in engineering education always follows a main line, which is a logical main line composed of three important dimensions: power, institution and technology.

Quality management first requires the presence of “power”, which refers the continuous intervention of various stakeholder groups; secondly, it requires the guarantee of “institution”, which refers the system design of organization, policies, and systems; and finally, it requires the logic of “technology”, which refers the scientific operation of related concepts, models, procedures, methods, etc. The presence of “power”, relying on the guarantees of “institution”, and through the logic of “technology”, continuously promotes quality assurance. This main line forms the systematic thinking and action logic of quality assurance in engineering education, and organically integrates the subjects, organizations, policies, systems, philosophy, procedures, technology, etc. What is reflected behind this main line is the logic of
power, institution and technology. Among them, the logic of “institution” is the hub that connects the logic of “power” and “technology”, and the logic of “technology” is the carrier of the logic of “institution” and “power” (see Figure 1).

Figure 1 Logical Model of the Internal Quality Assurance Mechanisms of Engineering Education

4.3 The model demonstration of the internal quality assurance mechanism of engineering education: Case of the Internal Quality Assurance Mechanism of American Higher Engineering Education

(1) Transfer from conservative response to active participation, form a student-centered and outcome-based educational philosophy, and shape an endogenous quality culture

The mid-1990s witnessed the ABET innovation which achieved the transformation of accreditation paradigm. It provided an opportunity for ABET to put forward the new accreditation criteria-EC2000, which brought a profound impact on engineering education within colleges and universities. In order to cope with the transformation paradigm of program accreditation, colleges and universities carried out various engineering education reform which included the exploration of a variety of learning outcomes assessment methods, the engagement of a wide range of intellectual resources, the internalization of the philosophy of continuous quality improvement, the integration of evaluation management mechanism, the in-depth reform of curriculum and teaching, and the talents cultivation in line with the EC2000 standard.

(2) Understand the concept of continuous quality improvement, explore rigorous procedures and techniques of program assessment, and establish a continuous technical improvement mechanism

Essentially, program accreditation requires the future accredited program to establish an effective mechanism for continuous improvement. Under the background of EC2000 reform, many colleges and universities integrated the philosophy of continuous improvement into program quality assurance in accordance with their own characteristics of program development, and put up with several proven continuous improvement models. Each program is required to prove that their graduates have 11 competencies stipulated by EC2000 criteria 3; form program assessment scheme, record assessment result, and prove that these results will
be applied to further develop and enhance program education; prove that the qualitative results of these assessment schemes can demonstrate the school’s task and teaching objective. Each program is required to constantly conduct self-evaluation of teaching objective and process via appropriate and normative assessment tools which need to be refined and improved. Quality assurance in engineering education not only requires teachers to put more effort in teaching, but also master the specialized knowledge and skills needed for continuous improvement. Engineering teachers use diversified assessment methods of program including conventional assessment methods of learning outcomes, develop new assessment methods, and positively reflect the reliability and validity of various assessment methods.

(3) Improve the hierarchical, functional and formal mechanisms, meet the requirements of ABET paradigm transformation, and establish a friendly management support mechanism

Quality assurance in engineering education is a comprehensive, systematic project, including a series of institutions, policies, resources and support. First, colleges and universities have developed mature and sound quality assurance organization at the school level, and actively established quality assurance organization at the college/department level. In order to meet the accreditation requirements, engineering departments of colleges and universities gradually integrated EC2000 accreditation criteria and philosophy into the quality assurance system, and established assessment management system at the college/department level by integrating evaluation and management mechanisms. Secondly, colleges and universities developed incentives to lead faculty to participate in quality assurance; developed policy which carried out new recruited faculty’ training, and led the new recruited faculty’ growth; established specialized organizations which promoted the professional development of teachers; developed students’ development policy; established internal educational evaluation system including school-level evaluation system, department-level evaluation system, program-level evaluation system, course-level evaluation system, which provided a good guarantee for internal quality assurance in engineering education.

(4) Intervene in the quality assurance in engineering education in different forms, and establish a coordinated power participation mechanism

Continuous improvement of undergraduate engineering education requires systemic reform which continuously integrates the school and various departments and requires that three strands of power-students power, academic power and administrative power—must appropriately involve this systemic reform process, in order to achieve continuous improvement of program. Stakeholders of engineering education not only include teachers, students and parents, but also include state legislators, alumni, practitioners and industry representatives who hire graduates. The powers have different attitudes and behaviors of participating in quality assurance.

5. Conclusion

Program accreditation of engineering education is an important measure to promote the connotative development of engineering education. How to give full play to the continuous
boosting role of engineering education to the reform and development of program accreditation of engineering education has become a strategic and practical issue that needs to be solved urgently. This research focuses on internal quality assurance issues, which is a rational exploration of seeking the connotative development of engineering education. Education must be restricted by social politics, economy, and culture, and will have an effect on the economic, political, and cultural development of society. Different political environments, economic systems, cultural traditions, and educational systems determine the quality assurance in engineering education in different countries and regions. Therefore, the explanatory power and universality of the logical model initially constructed by this research need to be further studied and verified.

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