Quality Assurance System of Talent Cultivation under the Framework of Educational Maturity Model

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***Abstract*—Based on the Capability Maturity Model (CMM), the Education Maturity Model (EMM) is proposed and the corresponding standards and key issues at each level are analyzed. Under the guidance of EMM, the quality standards of each step in the talent cultivation process are established. The quality assurance system is further built to realize the normalization, standardization and refinement management of talent cultivation. Based on the fine-grained measurement of the talent cultivation process and the scientific evaluation data of the talent cultivation quality, a closed-loop cultivation system that can be continuously optimized and improved is formed. The practice of the talent cultivation quality assurance system based on the EMM framework in the School of Computer Science, Shenyang Aerospace University shows that the total number of teaching research projects increased by 50%, and the number of students participating in science and technology competitions and the proportion of winning prizes increased by about 1 time.**

***Keywords*—education maturity model, quality assurance system, refinement management, scientific evaluation, continuous improvement introduction**

I. Introduction

In September 2018, the "Opinions of the Chinese Ministry of Education on Accelerating the Construction of High-Level Undergraduate Education and Comprehensively Improving Talent Cultivation Ability" pointed out that "taking the level and quality of talent cultivation as the primary indicators for evaluating universities [1]". In recent years, with the in-depth development of Professional Certification of Engineering Education and the implementation of the "Double Ten Thousand Plan" in China, high-quality talent cultivation has become the general goal of higher education reform. The foundation of various reforms is the construction of a talent quality assurance system, whose completeness and effectiveness are the key to ensuring the quality of talent cultivation [2].

However, the quality assurance system is generally lagging or insufficient in the construction of various majors. These shortcomings are as follows:

(1) Most majors and teachers have inaccurate grasp of the knowledge system and ability system, and the design of programmatic documents such as training programs and syllabus is not scientific.
(2) In the process of talent cultivation, the management granularity is not fine, accurate, and comprehensive enough. The education roles lack effective coordination in the planning and implementation process, and the responsibility system is not in place.
(3) The examination content in the teaching link cannot effectively support the evaluation of teaching ability achievement. Teachers lack the fine-grained data and processing methods to guide teaching improvement.
(4) There are many contents and links in the quality assurance system, which brings a lot of workloads to the evaluation of teaching, learning and management. It is difficult to guarantee the effectiveness of its implementation [3].

II. Construction of Educational Maturity Model

The Capability Maturity Model (CMM) was researched and released by the Software Engineering Institute (SEI) of Carnegie Mellon University in 1987. The CMM framework is divided into five levels, namely the initial level, the repeatable level, the defined level, the managed level and the optimizing level [4]. The CMM is suitable for complex engineering management. In addition to its application in the field of software engineering, it is also widely used in human resource management, systems engineering, integrated product development, enterprise management and other fields. Such as the People Capability Maturity Model (P-CMM) [5], the Business Process Management Model (BPMM), "Data Management Capability Maturity Model" (DCMM), the Open Digital Maturity Model (ODMM), etc.

The cultivation of higher education talents itself is also a complex project management problem. In 2018, the Chinese Ministry of Education issued the "National Standards for Undergraduate Professional Teaching Quality in General Colleges and Universities" (hereinafter denoted as the "National Standards"), and made it clear that on the basis of "National Standards" the three-level

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certification work of "guaranteeing qualifications, improving standards, and pursuing excellence" should be carried out. The three-level certification focuses on the ability, level and quality of undergraduate majors.

However, the implementation of the above three-level certification lacks fine measurement strategies. Hence, the Education Maturity Model (EMM) is proposed based on the connotation of CMM, which is used to evaluate the level of education and teaching, as shown in Fig. 1. In addition, under the background of Professional Certification of Engineering Education and national first-class professional construction, the idea of EMM is used in professional construction, focusing on promoting the construction and improvement of the quality assurance system.

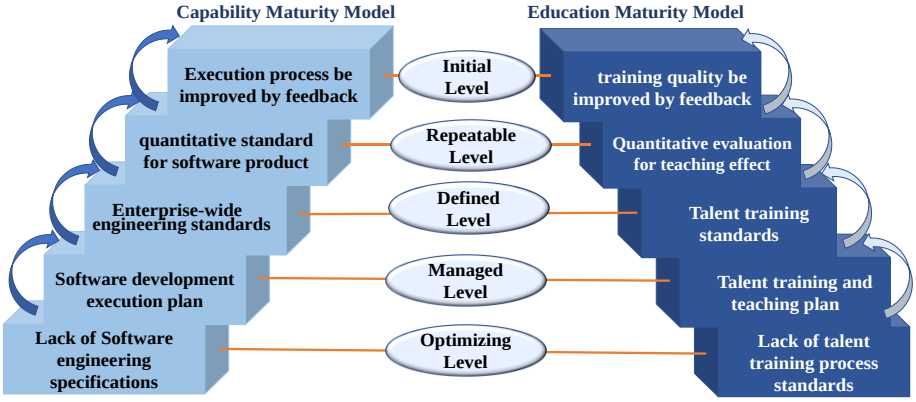


Figure 1. Correspondence between CMM and EMM.

III. Construction of Quality Assurance System Based on Educational Maturity Model

A. Normalization of "Repeatable Level"

The key process areas of the repeatable level include talent demand analysis, training plan determination, teaching plan formulation, and the establishment of necessary quality assurance systems such as teacher and student behavior standards, student status and credit management. Among them, a comprehensive analysis of the internal and external needs of talents is the foundation. Only in this way can the talent cultivation objectives of the majors be clarified and implemented in terms of graduation requirements and indicators. The achievement of graduation requirements can be supported by reasonable curriculum system design and effective teaching plan implementation, thereby supporting the achievement of cultivation goals.

1) Design of cultivation goals and graduation requirements

The cultivation goal is an overall description of the achievements in career and major that professional graduates can achieve about 5 years after graduation. The major must be based on the foundation of morality and the cultivation of students. In addition, it is necessary to fully consider internal and external needs and conditions such as the orientation of the school, the resource conditions of the major, the social needs and the expectations of stakeholders. Through expert seminars, graduate surveys, business visits, professional teacher seminars and other methods, stakeholders can reach a consensus on the connotation of cultivation goals.

Graduation requirements are a specific description of the knowledge, abilities and qualities that students should master when they graduate through the cultivation of this major. In addition, graduation requirements serve as a mapping node between the cultivation goals and the curriculum system, and play a role in linking the previous and the next. It can guide the establishment of the curriculum system, form the curriculum goals [6].

2) Curriculum system design guided by the ability requirement of "complex engineering problems"

Many standards in the engineering education certification involve "complex engineering problems" [7]. It can be seen that cultivating students with the ability to solve complex engineering problems is the basic orientation of undergraduate engineering education. The cultivation of students' ability to solve complex engineering problems must be realized through the cultivation system. The design of the curriculum system and the implementation of teaching are the main ways to support the cultivation of the ability [8].

Taking the computer-related fields as an example, to solve the complex engineering problems, students not only need to have professional skills such as computational thinking, algorithm design and analysis, program design and implementation, system design and implementation, system analysis and evaluation, but also professional norms, communication, teamwork, and self-improvement ability, etc. [9]. The corresponding curriculum system and teaching plan can be designed according to relevant ability requirements as illustrated in Fig. 2.

B. Standardization of "Defined Level"

The definition level focuses on the organization and implementation of the talent cultivation process. Its key areas include clarifying the focus issues that affect the quality of talents, realizing the standardization and documentation of each link of teaching and management work, and clarifying the responsibilities of each role in the process of talent cultivation. It has a complete teacher

training system and teaching supervision and review system, so that teaching and management activities can be controlled.

1) Normalization of system standards, realization of normal evaluation

According to the cultivation goals, graduation requirements and the dependence of each teaching link, the quality requirements of all teaching links are clarified, and the quality standards are refined [10]. A series of output-oriented quality management rules of teaching process and teaching document templates should be formulated to cover the whole process of undergraduate talent cultivation. Then, according to the quality standards of the teaching process, the quality supervision mechanism is refined combining with the teaching process management experience. These mechanisms specifically include the setting and revision of the curriculum system, the formulation and review of the curriculum syllabus, the supervision and inspection of course teaching process, the review of assessment methods and content of courses, evaluation of the achievement of graduation requirements, the tracking and feedback on graduates, and the social evaluation, etc., to achieve quality monitoring and evaluation throughout the entire process [11, 12].

2) Refinement of the division of roles, responsibilities in place

In the process of talent cultivation, teachers, course leaders, professional leaders, academic system personnel, teaching management personnel and other roles all have certain responsibilities. On the basis of clarifying and detailing the responsibilities of each role, the communication and coordination between roles should be emphasized. In particular, to ensure the quality of all links in the process of talent cultivation, it is necessary to pay attention to the coordination between talent quality tracking and the revision of training plan, the coordination between cultivation plan – syllabus – implementation of teaching activities, the coordination between teaching process organization – fine-grained assessment and evaluation – academic early warning and assistance.

C. Refinement of "Management Level"

The key area of the management level is to realize the quantitative management and evaluation of the talent cultivation process. Curriculum teaching is the basic link of talent cultivation, and course assessment is the main way to quantitatively evaluate teaching quality. Therefore, the rationality of teaching design, the comprehensiveness and accuracy of course assessment are the top priorities of quantitative evaluation.

1) Refinement of teaching requirements, guiding curriculum teaching design

The implementation of teaching should be output-oriented and decompose step by step in accordance to graduation requirements-indicators-course objectives-teaching requirements at the level of knowledge points" [13]. The basic teaching requirements of each knowledge point under the knowledge module in the professional knowledge system should also be clear, take this as a guide, plan the course teaching and course assessment, and implement it in the teaching implementation and assessment evaluation. so that each class hour can play its due role and each subject of the course assessment can accurately evaluate the achievement of the corresponding ability, then realize the teaching improvement based on evaluation [14].

2) Evaluation of the teaching process, clearly controlling the learning effect of students

The teaching process is the process of the formation of students' abilities. In the teaching process, a rich and measurable evaluation of the teaching process can be set up through the "small goal continuous assessment" method. Based on the evaluation data, the teacher can know the students' mastery and application of knowledge in time, so as to deal with the problems and improve the teaching implementation in time. In turn, data-driven early warning of learning status can be realized, which can further provide a basis for the development of personalized teaching.

D. Closed-Loop of "Optimization Level"

The optimization level is a process of continuous improvement of the quality of talent cultivation. Through quantitative means to identify the links that can be improved in the talent cultivation process, and by selecting teaching methods and cultivation models that play a role in improving the quality of talents and process goals, the optimization of the talent cultivation process is systematically and implemented.

1) Establishment of a multi-level closed loop mechanism, guiding the improvement of the inner loop based on the evaluation of the outer loop

The continuous improvement mechanism is shown in Fig. 3. The problems in the course teaching can be found through the innermost achievement evaluation of course objectives, and the teaching quality can be improved by reforming teaching methods, teaching methods, optimizing teaching content, and assessment methods. The deficiencies in some aspects of students' abilities can be found through the achievement evaluation of graduation requirements, and the curriculum support for the corresponding graduation requirements can be strengthened by guiding the setting of the curriculum system. The achievement evaluation of training objectives can assess the gap between the graduate's ability and the expected ability of the major, and be used to guide the setting of graduation requirements and the establishment of indicator points.

2) Introduction of new concepts and models, promoting education reform

The problems in each training link can be accurately discovered by scientific and accurate evaluation, so as to urge teachers, teaching *administrators*, and the person in charge of the major to think, learn new teaching concepts, and introduce new talent cultivation models. For example, strengthen the cultivation of computational thinking to improve the ability of problem analysis, and carry out the teaching of engineering case sets to improve the ability of

engineering practice. New models such as the integration of science and education, school-enterprise collaborative training [15], and empowerment education have been widely used in the reform of talent cultivation.

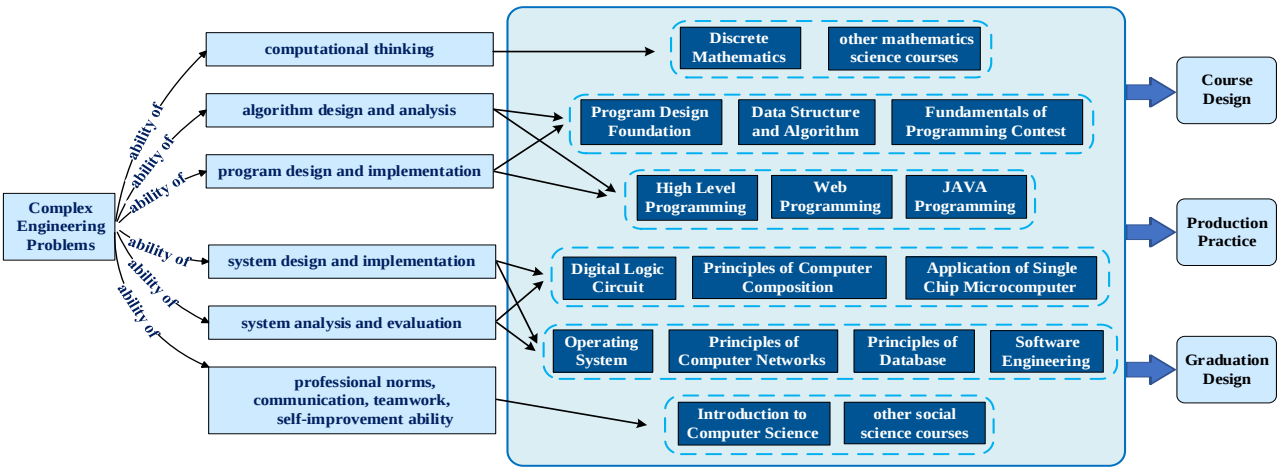


Figure 2. Curriculum system design of computer-related major.

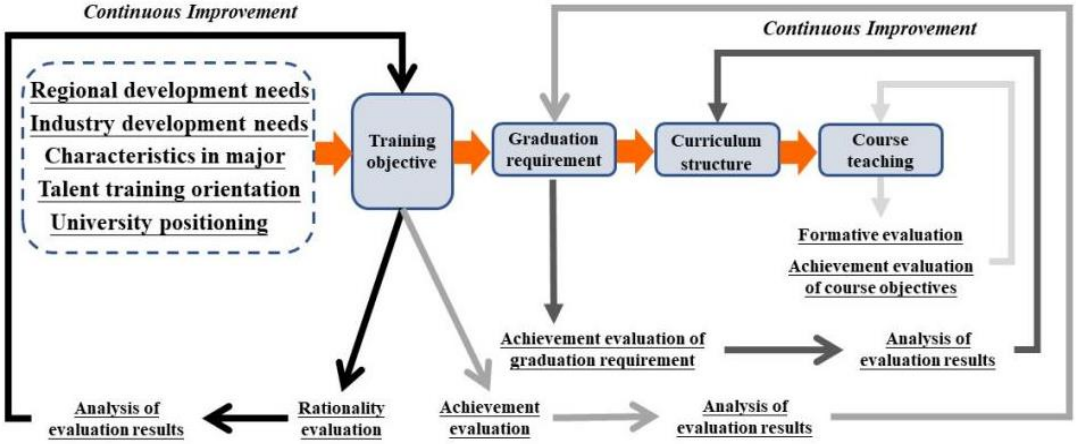


Figure 3. Mechanism of continuous improvement.

IV. Efficient Implementation of the Assurance System Based on Informational Teaching Management

The implementation process of the quality guarantee system has many links, with a large number of detailed standards, teaching management workload, and teaching activity evaluation data, and the use of high-level and high-efficiency information technology is the key to ensuring its standardized and orderly operation [16].

1. Fine management by means of information technology, realizing collaborative cultivation. Majors can make full use of intelligent teaching tools, course teaching platforms, practical teaching management systems, academic early warning systems and other teaching information systems to support the fine assessment of courses and the information management of the teaching process and establish a multi-level early warning and feedback mechanism [17]. Teachers, students, and counselors can communicate efficiently through the information platform, which can realize the coordinated training of "teaching-learning-management". The information system has accumulated a large amount of teaching and learning behavior data of teachers and students, teaching content data and quality monitoring data. Through the quantitative analysis of the above data, students' learning status and teachers' teaching attitudes can be accurately grasped, which can help teachers and students reflect on their own teaching and learning problems, and further improve and adjust their own behavior in time [18].

2. Construction of students' digital portraits, supporting personalized cultivation. Through the construction of an information system covering the full cycle of talent cultivation, such as course teaching, internship practice, achievement evaluation of teaching effect, survey feedback, etc., individual data of students can be obtained in multiple dimensions and their digital portraits can be drawn. Fig. 4 shows the achievement of individual graduation requirements of Computer Science students. It can directly show the difference between the students' various abilities and the deficiencies of certain abilities, which can guide the follow-up teaching. As a result, the pertinence of teaching is improved, and the personalized cultivation of talents is effectively supported.

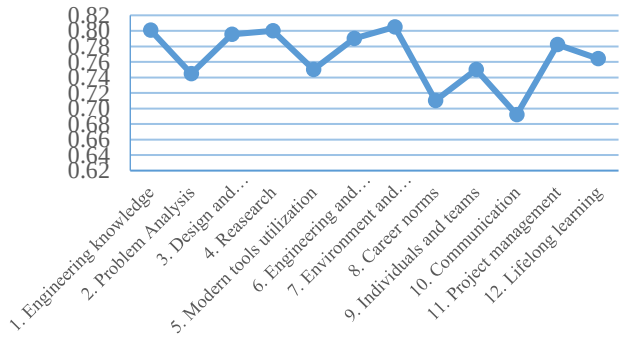


Figure 4. Achievement of individual graduation requirements of computer science students.

V. Reform Effect Based on EMM

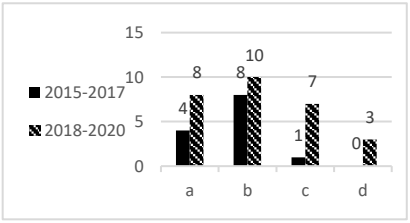
The College of Computer Science, Shenyang Aerospace University takes fine management and scientific evaluation as the core, and accurately implements the operation of the talent cultivation quality assurance system by means of information technology. Since the implementation of the reform of the quality assurance system for talent cultivation, the achievements are as follows:

(1) *The curriculum system has been optimized to improve the quality of repeatable level, strengthen school-enterprise collaboration, and support empowering education*. The curriculum design respects the reform ideas from the knowledge system to the ability system, and continues to carry out the construction of the curriculum group to realize the through-type training of knowledge content and ability. The curriculum system focuses on cultivating students' international vision and offers "competitive frontier optional courses". In these courses, cutting-edge and innovative teaching content has been added to promote the integration of new technologies such as artificial intelligence and big data with the curriculum system. In addition, the system also strengthens students' practical ability and innovation ability Straining through various methods such as enterprise participation in teaching, practical link guidance, and subject competition guidance.

(2) *The quality assurance system for talent cultivation has been built with standards as the core*. A large number of regulations and curriculum document templates have been compiled and revised, such as process assessment management, talent tracking feedback, achievement evaluation of graduation requirements, etc. The annual teaching document file number is nearly 7,000, and the fine-grained evaluation management of talent quality and teaching effect has been realized. As a result, the scientific nature of the defined-level evaluation method is improved, and the evaluation results are quantified, which supports teachers to reflect on the teaching in depth, and makes the education trend more and more optimized.

(3) *The construction of informatization has provided a strong assurance for management level and optimization level.* Twelve information systems including practical teaching monitoring, academic early warning, and talent quality tracking have been developed and constructed, and nearly 700 GB of evaluation data on teaching process has been accumulated. These data have also provided a basis for teaching reform. Fig. 5 shows the comparison of teaching reform research projects between 2015–2017 and 2018–2020. The total number increased by 50%, and the percentage of research projects based on teaching big data reached 38.89%, which shows that EMM has been approved by teachers.

(4) *The EMM of multiple majors has been upgraded from the original Defined Level to the precise Managed Level, and has the continuous improvement mechanisms of Optimizing Level, which effectively improves the quality of talent cultivation.* In the past three years, students from the School of Computer Science have won nearly 400 awards at or above the provincial and ministerial level, including 55 national awards. Intern students who are paid in companies account for 35% of fresh graduates. And the admission rate for postgraduate entrance examinations is about 30%, of which the admission rate for double first-class universities is about 9%. The major of Computer science and technology has passed the engineering education certification, and the first batch of national first-class majors construction sites has been approved. Fig. 6 shows the students' participation and awards in science and technology competitions from 2016 to 2020. 400 students participated in science and technology competitions in 2020, of which 86 won national awards, accounting for 21.32% of the total number of participants which verifies the effectiveness of the EMM.



a: Provincial-level or above teaching reform projects
b: University-level teaching reform projects
c: Teaching Big Data Research Project
d: Provincial-level or above teaching achievements

Figure 5. Teaching reform research projects in 2015–2017 and 2018–2020.

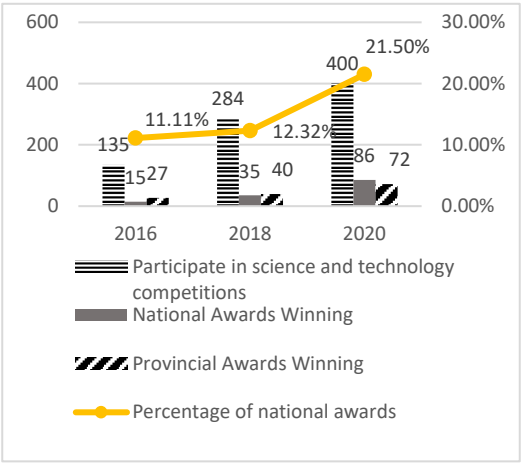


Figure 6. Student participation and awards in science and technology competitions in 2016, 2018 and 2020.

VI. Conclusion

In order to solve the problems in the quality of higher education talent cultivation, the concept of Educational Maturity Model (EMM) is proposed for the first time, and the key elements in each level were clarified in the model. The EMM takes fine management and scientific evaluation as the central idea, and effectively uses it in the construction of the talent quality assurance system, so as to realize the normalization, standardization and refinement of talent cultivation. And through the utilization of information technology to effectively support the operation of the quality assurance system, thereby reducing the cost of teaching management, promoting education and teaching reform, and improving the maturity of education.

Conflict of Interest

The authors declare no conflict of interest.

Author Contributions

Lihui Cong and Jiajia Li proposed and established the educational maturity Model and wrote the paper; Dang Wang and Xiangqin Liu improved the quality standard of definition level in the model and analyzed the data; Liang Zhao and Chunlong Fan constructed and applied the educational informatization; all authors had approved the final version.

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