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Research on the Construction of Post Competency Model and Competency Map for Software Engineering Major under the Background of Emerging Engineering Education

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Abstract: Against the background of the deep integration of Emerging Engineering Education construction and digital economy, to address the challenges of vague competency standards and fragmented training paths in software engineering talent cultivation, this study first constructs a quantifiable post competency model using the Onion Model as the framework, combined with the Delphi method and coefficient of variation method. Furthermore, based on this model, a three-level progressive competency map of "Basic Competency–Professional Competency–Innovative Application Competency" is designed and refined into observable training indicators throughout the four-year undergraduate program. The research results lay a foundation for the precise industry-education connection and the subsequent construction of smart courses.

Keywords: Emerging Engineering Education; Post competency; Competency map; Software engineering; Delphi method

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1. Introduction

With the in-depth advancement of Emerging Engineering Education, the rapid transformation of industrial technology has put forward an urgent requirement for the systematic reconstruction of the engineering talent training system. The state has intensively issued policies to promote the cultivation of digital talents and the digital transformation of education, providing clear guidance for the educational reform of software engineering and the construction of smart courses. In 2024, nine departments including the Ministry of Human Resources and Social Security jointly issued the *Action Plan for Accelerating the Cultivation of Digital Talents to Support the Development of Digital Economy (2024–2026)*, which clearly proposed to increase the effective supply of digital talents. In the same year, the Ministry of Education launched the "AI

Empowerment Action" to promote the all-round empowerment of education by artificial intelligence and cultivate professional digital talents [1,2]. In this context, enterprises require software engineering talents to possess comprehensive capabilities of in-depth technology, comprehensive literacy, and the ability to solve complex engineering problems. However, the current curriculum system can hardly meet such demands and is in urgent need of systematic reform.

Driven by the above national policy orientation and industrial development demands, relevant investigations have shown that the drawbacks of the knowledge-oriented training model in software engineering are becoming increasingly prominent. The main contradictions focus on two aspects: first, the disconnection between courses and post demands, lagging update of teaching content, and low supply-demand matching; second, the fragmentation of competency training, lack of effective connection between courses, and failure to form a progressive competency training system [3]. To address these dilemmas, this paper accurately anchors the core demands of enterprises by constructing a post competency model, and better serves the talent training of software engineering by designing a competency map.

2. Research on relevant theories and methods

2.1. Theoretical evolution and application of post competency model

The theory of post competency was formally proposed by McClelland in 1973, which is mainly used to predict individual performance in specific work scenarios. Among them, the most famous analytical framework is the Onion Model. The Onion Model designs competency as a progressive concentric circle structure, which from the outside to the inside includes knowledge and skills, self-concept, traits, and motives. The model highlights the internal correlation and progressive logic of cultivation among various elements. Driven by engineering education accreditation, curriculum reform based on the concepts of outcome-based education (OBE) and student-centeredness has become a consensus. The post competency model provides a concrete and structured source of competency standards for the graduation requirements in the OBE concept. Domestic scholars have attempted to construct post competency models in media, rehabilitation, library and information science, and other professional fields to guide curriculum system reform. However, for software engineering, a major with rapid technological iteration, existing studies mostly stay in the qualitative description of general competencies and lack a competency model with quantifiable weights, leading to vague competency standards that are difficult to be directly used for precise curriculum objective design.

2.2. Concept, function, and educational application of competency map

A competency map is a tool that systematically decomposes, hierarchically organizes, and visually presents the competencies required to complete a specific professional role or learning goal. Its core functions are to clarify: what competencies need to be cultivated, to what level these competencies should be achieved, and through what paths and sequences to cultivate these competencies, so as to solve the problems of scattered competency training and poor curriculum connection in traditional teaching. In the field of education, the application value of competency maps has become increasingly prominent. Domestic scholars have carried out beneficial explorations in textbook development, ideological and political education in courses, and curriculum system reform. Foreign studies also emphasize that constructing a competency map consistent with academic and industrial demands is the key to improving graduates' employability. However, existing studies have two shortcomings: first, most competency maps are constructed without a scientifically verified post competency model as the basis, resulting in insufficient scientificity and authority; second, the application of competency maps in higher engineering education, especially how to refine and implement from macroscopic maps to microscopic and observable teaching indicators, is still insufficiently studied.

2.3. Research methods

This paper adopts a combination of the Delphi method and the coefficient of variation method. The Delphi method gradually converges expert opinions through multiple rounds of anonymous expert consultations, so as to efficiently and systematically obtain group consensus on the post competency elements and their importance for software engineering. The coefficient of variation method is an objective weighting method, whose core is to quantify the dispersion degree of opinions on each competency element among experts by calculating the coefficient of variation of expert scoring data. This method weights completely based on the statistical characteristics of the data itself, effectively avoiding the deviation caused by subjective assignment, and can adapt to the precise quantification requirements of post competency for software engineering.

3. Key research ideas

Focusing on the talent training of software engineering and the precise connection between industrial demands and educational supply, this paper carries out two main tasks: constructing a competency model and developing a competency map. First, this paper focuses on three core positions (software development engineer, software test engineer, system architect/designer) that graduates of software engineering mainly engage in, constructs a quantifiable post competency model, and establishes the competency dimensions, elements, and weights of the positions. Second, based on the post competency model, this paper develops a hierarchical and progressive competency map, combines the four-year undergraduate training cycle of software engineering, and refines it into grade-based and observable training indicators, realizing the visual navigation and phased implementation of competency development [4,5].

4. Construction and weight analysis of post competency model

4.1. Model construction

Based on the hierarchical theoretical framework of the Onion Model, combined with the job characteristics of core positions in software engineering and the opinions of enterprise surveys and expert interviews, this paper constructs a post competency model including four dimensions and 16 key elements. The four dimensions of the model are: professional knowledge, technical skills, professional quality, and behavioral performance, in the logic from basic to application. The 16 key elements include: algorithm design, network protocols, operating systems, and data structures in the professional knowledge dimension; programming implementation, AI tool application, domain knowledge, and software testing in the technical skills dimension; team cooperation awareness, critical thinking, lifelong learning awareness, and artificial intelligence literacy in the professional quality dimension; project implementation, complex problem diagnosis, technology integration and innovation, and achievement transformation in the behavioral performance dimension.

According to the importance of competencies, post demand levels, and training difficulty, this paper divides the above 16 competency elements into three categories: basic elements, core elements, and advanced elements. Among them, basic elements correspond to professional knowledge, which is the premise of professional learning; core elements correspond to the main content of technical skills and professional quality, which is the key support for post performance; advanced elements correspond to behavioral performance and comprehensive innovation ability, which is the concentrated embodiment of core competitiveness of talents. The post competency model of software engineering is shown in **Figure 1**.

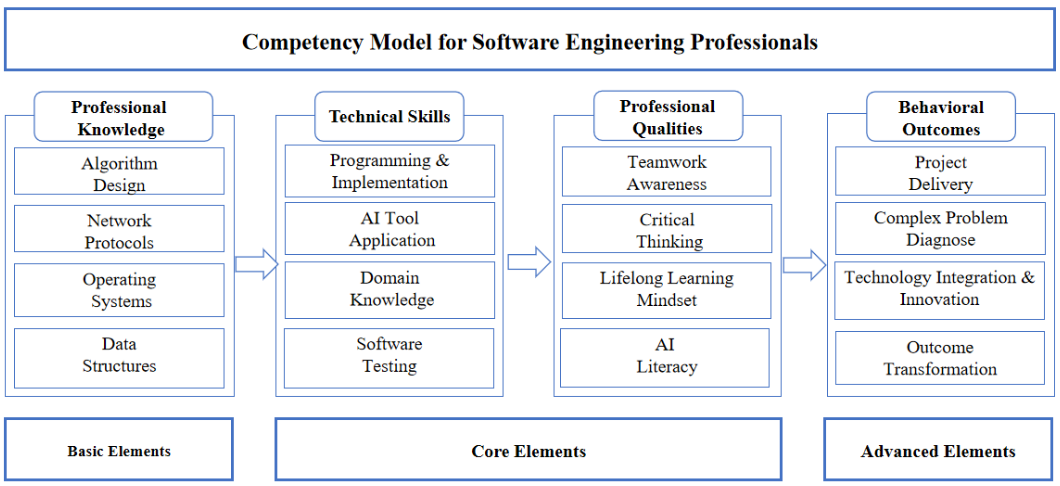

Figure 1. Competency model for software engineering professionals

4.2. Model verification and weight determination

To ensure the scientificity and practicability of the model, this paper adopts the Delphi method and invites 10 experts with more than 5 years of experience in relevant fields to conduct multiple rounds of evaluation on the dimensions, elements, and weights of the core post competency model of software engineering. The study adopts a 5-point scale and achieves opinion convergence through three rounds of anonymous questionnaires: the first round collects modification suggestions and initial evaluations based on the preliminary model; the second round feeds back the group statistical results and revision instructions for experts to adjust scores; the third round confirms the final model. Finally, based on the third round of expert scores, the coefficient of variation method is used to calculate the weights of each element and dimension. The weights of each dimension and element are as follows:

(1) Professional knowledge (30%): algorithm design (8%), network protocols (6%), operating systems (8%), data structures (8%).

(2) Technical skills (35%): programming implementation (12%), AI tool application (10%), domain knowledge (5%), software testing (8%).

(3) Professional quality (15%): team cooperation awareness (3%), critical thinking (4%), lifelong learning awareness (3%), artificial intelligence literacy (5%).

(4) Behavioral performance (20%): project implementation (5%), complex problem diagnosis (6%), technology integration and innovation (5%), achievement transformation (4%).

5. Development of hierarchical and progressive competency map

5.1. Map transformation logic and framework construction

To transform the post competency model into an executable training path, this paper reorganizes its elements pedagogically according to competency complexity, cognitive development laws, and the four-year training cycle, and transforms it into a three-level progressive structure of "Basic Competency–Professional Competency–Innovative Application Competency." Among them, the basic competency layer corresponds to the basic elements of the model, aiming to lay professional cognition and engineering behavior norms. The professional competency layer corresponds to the core elements of the model, forming structured professional competency to solve typical engineering problems in specific fields through systematic training. The innovative application competency layer corresponds to the advanced elements of the model, guiding students to carry out comprehensive innovative practices aiming at value creation in complex and uncertain real engineering environments. The hierarchical post competency map of software engineering is shown in **Figure 2**.

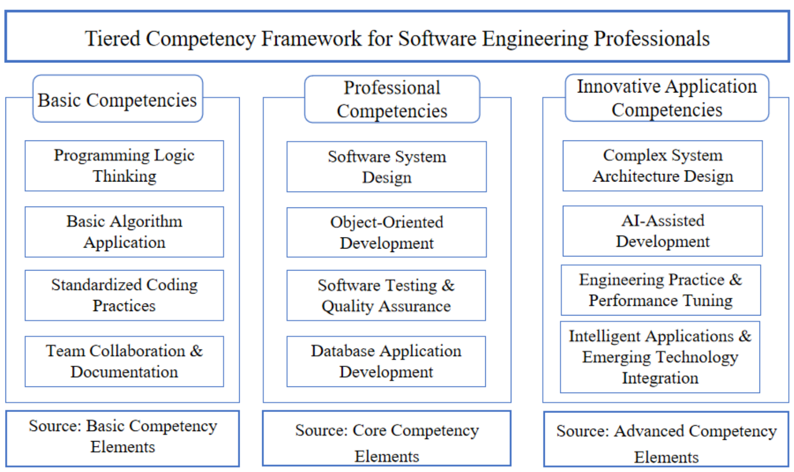

Figure 2. Tiered competency framework for software engineering professionals

5.2. Refinement of observable indicators

This paper maps the hierarchical competency map to the four-year undergraduate training cycle, forming a spiraling competency advancement channel.

(1) The first year is positioned as the enlightenment and standardized training of engineering thinking, aiming to enable students to have the ability to use programming languages to solve basic problems.

(2) The second year realizes the transition from general basic knowledge to professional technology. On the basis of mastering object-oriented and system modular design, students need to establish basic cognition of databases and front-end and back-end architectures, and undertake corresponding module responsibilities in the team development process.

(3) The third year focuses on the internalization of professional technology and engineering implementation. Students are encouraged to independently complete the design and implementation of small and medium-sized full-stack systems, undertake core development tasks in the team, and exercise practical ability to solve complex problems.

(4) The fourth year faces comprehensive innovation in real engineering scenarios, promoting students to participate in enterprise-level project practice, strengthening system diagnosis and optimization capabilities,

leading the delivery of comprehensive projects through graduation design or internship, and finally realizing the high-level aggregation and actual value transformation of knowledge, skills, and literacy.

6. Conclusion

By constructing a quantifiable post competency model and a hierarchical competency map for software engineering, this paper provides a systematic theoretical framework and practical tool to solve the problem of disconnection between talent training and industrial demands. The research not only scientifically defines post competency standards, but also plans a clear progressive path of competencies, realizing the mapping from the demand side to the training side. The research results provide a direct basis for the curriculum system reform of software engineering in colleges and universities, and have important reference value for promoting the innovation of talent training models under the background of Emerging Engineering Education.

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