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Construction and Application of Job Competency Map for the Silicon Material Industry

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Abstract: This paper takes the professional group of silicon material preparation technology as its research object. It explores the role of the job competency map as a transitional bridge connecting industrial demands and talent cultivation, clarifies its underlying theoretical logic, and outlines practical pathways for implementation. The core function of the job competency map is to transform the often implicit and unquantifiable ability requirements of corporate positions into clear, actionable, codifiable, and assessable standards for talent development. The overall construction process adheres to the sequence of "industry research — job analysis — competency deconstruction — coding expression." Accordingly, this study establishes a three-level job coding system, designs the "L-N Job Competency Grading Matrix" evaluation model, and establishes a closed-loop talent cultivation operational mechanism of "map construction — factor reform — effect evaluation — map optimization." Practical results demonstrate that the job competency map can effectively resolve the fragmented nature and isolated reform measures that often plague vocational education reforms. It provides a replicable and scalable implementation strategy for vocational colleges to align talent cultivation with the needs of strategic emerging industries.

1. Introduction

The silicon material industry serves as the fundamental raw material base for the photovoltaic (PV) and semiconductor sectors, playing a critically supportive role in the implementation of China's national "dual-carbon" strategy and the advancement of its energy transition[1]. Sichuan Province is strategically developing a trillion-yuan-level advanced materials industrial cluster, with Leshan, known as "China's Green Silicon Valley," already hosting the world's top five crystalline silicon company. According to Sichuan's industrial plan, the province aims to achieve a total PV industry chain revenue exceeding 500 billion yuan by 2027. The rapid expansion of the industry, coupled with continuous technological updates and iterations, imposes higher demands on both the quantity and comprehensive competencies of technical and skilled personnel.

The technological transformation of the silicon material industry is characterized by the interplay of multiple trends. Technologically, the market share of N-type high-efficiency cells is steadily

increasing, and the research and development of electronic-grade polysilicon is advancing, driving the entire industry towards higher value-added segments of the industrial chain[2]. In terms of processes, manufacturing is evolving towards larger dimensions, wafer thinning, and intelligent production. Regarding industrial development models, green production and circular utilization have become industry-wide consensus. These transformations are directly altering the competency requirements for corporate positions. In the past, employees were only expected to perform single-process operations; today, there is a greater emphasis on the integrated capability combining process control, data analysis, and intelligent equipment maintenance.

However, in reality, there remains a prominent structural contradiction between the talent output of vocational colleges and the job requirements of the industry. On the one hand, technological updates in the silicon material field are rapid, while the cycle for revising talent cultivation plans in educational institutions is relatively long. On the other hand, vocational colleges often lag behind corporate production realities in recognizing new positions and business models emerging within the industry, leading to a disconnect between graduate competencies and corporate job requirements. To resolve this practical contradiction, a mechanism is needed to translate dynamically changing corporate job demands into executable talent cultivation standards for educational institutions. The job competency map is a tool well-suited to this need. It is not a simple compilation of various job descriptions but rather a transitional carrier that decomposes industrial job requirements into specific competency units and further maps them to course teaching modules[3].

2. Theoretical Logic of the Job Competency Map

2.1 Paradigm Shift from "Curriculum Logic" to "Job Logic"

Traditional talent cultivation is based on the integrity of disciplinary knowledge systems, following the sequence of "disciplinary knowledge — curriculum design — teaching activities." In periods of relatively stable technological development, this model can largely meet the workforce demands of the industry. However, as industrial technology accelerates, the shortcomings of this model have become increasingly apparent: course content lags behind actual production, and a significant gap exists between the knowledge and skills students acquire on campus and the real requirements of corporate positions[4].

The construction of a job competency map shifts the focus of talent cultivation from "curriculum logic" to "job logic." Its core idea no longer revolves around "what content should be taught in courses," but rather starts from the practical needs of enterprises to clearly define "what competencies employees actually need for their jobs." It uses industrial talent demands as the starting point to retroactively determine the content and methods of educational supply. The essence of this paradigm shift is to move the basis of talent cultivation from disciplinary knowledge to actual job competencies, genuinely allowing industrial needs to guide the operation of vocational education.

2.2 The Competency Map as an "Industry-Education" Intermediary Mechanism

Functionally, the job competency map serves a tripartite intermediary role between the industry and education sectors. First, it acts as a cognitive intermediary, transforming implicit corporate expectations of job roles into clear and tangible competency items, thereby bridging the information gap between corporate needs and educational arrangements. Second, it functions as a standards intermediary, converting industrial job requirements into measurable and assessable competency standards, providing objective benchmarks for evaluating the quality of talent cultivation. Third, it serves as an action intermediary, leveraging the established competency standards to further align

corresponding course modules, teaching projects, and practical training tasks, thus paving the way for the full translation of industrial needs into educational implementation[5].

3. Practical Construction of the Job Competency Map for the Silicon Material Industry

3.1 Industry Research and Job System Structuring

The initial and crucial step in building the job competency map is conducting thorough on-site industry research. The research team surveyed key silicon material enterprises nationwide, covering the entire industry chain, including polysilicon preparation, monocrystalline silicon pulling, and silicon wafer processing. The primary objectives were to clarify two core issues: which key positions constitute the silicon material industry chain, and what specific competency requirements correspond to each position.

Based on the research findings, six major job modules were identified for the silicon material industry: raw material pre-treatment positions, core production positions, auxiliary support positions, quality inspection positions, equipment maintenance positions, and production management positions. Among these, trichlorosilane synthesis, rectification operations, and reactor operations are core frontline production roles, where operator proficiency directly impacts the quality and efficiency of polysilicon production. Positions such as equipment maintenance, finished product quality inspection, and central control room operation are critical support roles ensuring stable production operations.

The research also identified evolving trends in job competency requirements. For process control positions, the demand now extends beyond basic operations to include process analysis and parameter optimization capabilities. Quality inspection personnel are required to skillfully operate sophisticated instruments like ICP-MS and possess the ability to analyze and mine large batches of inspection data. The focus of equipment maintenance roles is gradually shifting towards the maintenance and debugging of DCS, PLC control systems, and industrial robots. Digital literacy has become a fundamental requirement, with practitioners needing proficiency in industrial software like MES and basic data analysis skills. Overall, there is a widespread demand across industry positions for interdisciplinary competencies, encapsulated as the integrated capability of "silicon materials + chemical engineering + automation + digitalization."

3.2 The Three-Level Coding System: Structured Expression of Competencies

Establishing a coding system is a critical technical step in constructing the job competency map. Its purpose is to organize the complex and varied competency demands into a structured, searchable coding system that facilitates pedagogical alignment. The design of the coding system strictly adheres to the principles of uniqueness, hierarchy, scalability, and practicality. The research team developed a three-level job coding architecture: "category code — sub-category code — specific item code." The category code distinguishes the business domain of the job, for example, "A" represents the polysilicon business domain. The sub-category code classifies major job categories, for instance, "II" denotes quality inspection and analysis positions. The specific item code corresponds to the numbering of individual competency items for a specific job. Through the combination of letters and numbers, the structured documentation of all job competencies is achieved.

The value of the coding system extends beyond mere classification. More importantly, it establishes a correspondence between "industry positions — competency dimensions — teaching elements." Each code set is accompanied by a clear competency description, and each competency requirement can be further broken down into corresponding course modules and practical training

projects. This “code-through” design ensures a unified reference point across the entire talent cultivation process.

3.3 The L-N Model: Graded Competency Evaluation

While the coding system clarifies which competencies are needed for a job, determining whether a practitioner’s abilities meet the job standard requires supporting evaluation tools. The research team developed the “L-N Job Competency Grading Matrix” evaluation model to enable quantitative comparison between job competency standards and the actual ability levels of learners. This model establishes a talent assessment framework based on four dimensions: professional knowledge, practical skills, comprehensive qualities, and professional values. By using the grading matrix, it precisely identifies a learner’s competency strengths and areas for improvement.

In practical application, this evaluation model can generate multidimensional talent profile reports, including competency radar charts, detailed competency level lists, strength-weakness analyses, and career development recommendations. This report serves multiple stakeholders: enterprises can use it for recruitment and internal talent assessment; students gain a clear understanding of their current competency status to plan their career development; and schools can rely on the evaluation data to provide an empirical basis for teaching reforms. The data generated from evaluations flows back into the closed-loop system of the competency map, providing support for subsequent map iterations and optimization.

4. From Map to Cultivation: Competency-Oriented Teaching Reform

4.1 Restructuring the Modular Curriculum System

The value of the job competency map lies primarily in its application. Leveraging the established competency map, the research team systematically restructured the curriculum system for the silicon material preparation technology professional group. The fundamental approach of this restructuring was to achieve a “competency-to-knowledge point” transformation, breaking down each coded job competency into specific knowledge units and skill points. These were then organized into modular courses according to a progressive logic of “introductory learning — core skills — advanced development.”

The restructuring of the curriculum system broke away from the traditional discipline-oriented course organization model. Course modules were no longer arranged in a simple linear sequence of “fundamentals first, specializations later.” Instead, project-based teaching sequences were designed based on authentic job workflows. Taking the competency code corresponding to reactor operation as an example, it encompasses equipment knowledge, process parameter control, production abnormality handling, and product quality inspection. The teaching module was developed to follow the actual operational sequence in the enterprise, allowing students to acquire the entire set of job-required competencies while completing project tasks.

4.2 Synergistic Reform of the “Five Elements”

The job competency map does not only impact curriculum development; it drives the coordinated reform of five key educational elements: programs, curricula, faculty, teaching materials, and practical training. At the program level, the map guides the dynamic adjustment of professional development directions, forming a professional cluster centered on silicon material preparation technology, encompassing photovoltaic materials, photovoltaic engineering, energy storage materials, and intelligent control technology. At the faculty level, it serves as a benchmark

to identify teacher competency gaps, guiding targeted professional development and corporate internships. At the teaching materials level, it informs the development of project-based textbooks and work sheets aligned with competency codes. At the practical training level, it guides the configuration of training equipment and the design of training projects that mirror authentic working conditions.

The reforms of these five elements—programs, curricula, faculty, teaching materials, and practical training—are not carried out independently. Instead, they are all coordinated and orchestrated around the central framework of the job competency map. This "map-led, five-element synergy" reform model effectively addresses the previous issues of fragmented and isolated initiatives in vocational education reform.

4.3 The Closed-Loop Mechanism: Institutional Guarantee for Continuous Iteration

The job competency map is not a static document. Industry technologies and corporate job requirements are constantly evolving, necessitating synchronous updates to the map's content. The research team established a complete closed-loop operational mechanism: "map construction → factor reform → effect evaluation → map optimization." An annual cycle of industry demand research is conducted to revise and improve the competency codes based on new industry technologies, processes, and standards. Evaluation data, such as the job adaptation of graduates and corporate satisfaction with hiring, are collected. Based on the evaluation feedback, the competency map and talent cultivation plans are then refined accordingly. This closed-loop mechanism ensures that talent cultivation remains synchronized with industrial development.

5. Conclusion and Discussion

Constructing a job competency map represents a systematic endeavor by vocational education to proactively adapt to industrial transformation. From a methodological perspective, the value of the job competency map is primarily evident in three aspects. First, it provides standardization, transforming scattered and implicit job requirements into a standardized and structured coding system, thereby offering an implementable reference for talent cultivation. Second, it ensures dynamism, relying on regular research and closed-loop feedback to keep talent cultivation standards aligned with industrial development, thus avoiding the problem of "infrequent revisions and long-term stagnation." Third, it promotes systematization, using the map as a connecting thread to unify program layout, curriculum development, textbook compilation, faculty development, and practical training conditions within a cohesive reform framework. This represents a transition from fragmented, single-point reforms to a systematic, holistic transformation.

Despite its potential, the construction and application of the job competency map still face several practical challenges. These include ensuring the accuracy and completeness of competency descriptions, balancing the standardization and flexibility of the coding system, and efficiently feeding evaluation analysis data back into the map optimization loop. These issues require further theoretical research and practical exploration. Nevertheless, the paradigm shift in vocational education from "curriculum logic" to "job logic," and from experience-driven operation to map-driven operation, represents an inevitable direction for aligning with industrial change. In the context of the rapid development of strategic emerging industries, the theoretical and practical value of the job competency map as a tool bridging industry and education will continue to grow.

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