

Three-Layer Coupling Model and Operation Mechanism of Cluster Cultivation of High-Skilled Talents Under the Guidance of Industrial Chain

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Abstract: Addressing the practical mismatch between vocational education talent cultivation and industrial chain demand in China, as well as the drawbacks of narrow cultivation scope, weak synergy and insufficient adaptability under the traditional single-specialty schooling model, this paper constructs a three-layer coupling model for high-skilled talent cluster cultivation. It takes industry-education integration as the underlying logic, high-skilled talent cultivation as the core goal, and cluster-based education as the organizational carrier. The model includes a structural layer for specialty-industry structural alignment, an implementation layer for precise competence-post matching, and a guarantee layer for multi-stakeholder collaborative ecology. Four closed-loop mechanisms are further proposed to ensure coordinated system operation. This model systematically restructures cultivation organization, pathways and support systems, effectively improving talents' post competence and industrial adaptability, and providing a systematic theoretical framework and implementation path for high-skilled talent cultivation in integrated high-end manufacturing and modern services.

Keywords: Specialty clusters, Three-layer coupling, Operation mechanism, Industry-education integration, High-skilled talents.

1. Core Principles and Overall Framework of Model Construction

The industrial chain-oriented cluster cultivation of high-skilled talents essentially embeds the division logic, competence standards and development demands of the industrial chain into the whole process of talent cultivation in vocational education, and realizes the optimal allocation of educational resources and systematic cultivation of talents through the clustered organizational form. The model construction is not an arbitrary splicing of elements, but a systematic design following industrial logic and educational laws, with the core embodied in the unity of three dimensions.

First, the unity of goals and demands. Taking the demand for high-skilled talents across the whole industrial chain as the fundamental guidance, industrial demands are transformed into clear talent cultivation goals. Through the specialty layout of clusters covering all core links of the industrial chain, the structural dislocation of talent supply is solved. The unity of goals and demands requires that the top-level design of talent cultivation must start from the industrial end rather than the disciplinary end, and transform the structural and competence demands of the industry into specialty setting goals and talent cultivation goals, so as to ensure that the direction of education is highly consistent with the direction of industrial development.

Second, the unity of processes and posts. Taking the high-skill requirements of posts in the industrial chain as the standard, the teaching implementation system is reconstructed. Through project-based and scenario-based teaching modes, the in-depth integration of teaching process and production process is realized, and the problem of competence disconnection in talent cultivation is solved. The unity of processes and posts requires that all links of teaching be benchmarked against the real work scenarios and competence

requirements of posts, break the barrier between theory and practice, allow students to complete competence development in real post tasks, and realize the transformation from knowledge learning to competence generation.

Third, the unity of subjects and mechanisms. Taking industry-education symbiosis as the core, a support system with multi-subject collaboration is built, and a full-cycle collaborative education mechanism is established to solve the problem of shallow school-enterprise cooperation and provide long-term support for the cluster cultivation of high-skilled talents. The unity of subjects and mechanisms requires breaking the pattern of single-subject schooling by colleges, and absorbing multiple subjects along the industrial chain such as government, industry and enterprises to participate in education. Through institutionalized mechanism design, the rights and responsibilities of all parties are guaranteed, and the endogenous motivation for collaborative education is stimulated.

From the overall architecture, the cluster cultivation model presents a three-layer coupling form of "structural layer - implementation layer - guarantee layer". The structural layer is the basic framework of the model, corresponding to the specialty layout of talent cultivation, and solves the structural problem of "what kind of talents to cultivate". The implementation layer is the core carrier of the model, corresponding to the teaching process of talent cultivation, and solves the path problem of "how to cultivate talents". The guarantee layer is the support system of the model, corresponding to the governance mechanism of talent cultivation, and solves the subject and motivation problem of "who cultivates talents". The three layers are interrelated and operate collaboratively, jointly forming a complete cluster cultivation system for high-skilled talents. At the same time, closed-loop management is realized through four operation mechanisms running through the whole process, ensuring the

dynamic adaptation and continuous optimization of the model.

2. Design of the Structural Layer of Specialty Clusters Adapting to Post Groups

Specialty clusters are the structural foundation of cluster cultivation. Its core is to reconstruct the specialty layout according to the whole-chain division logic of the industrial chain, form a specialty cluster configuration that precisely corresponds to the post groups of the industrial chain, and realize the transformation from “a specialty docking with a single post” to “a cluster docking with the entire industrial chain”.

The primary task of the structural layer is to systematically draw the post competence map of the industrial chain, which is the practical basis for the construction of specialty clusters. It is necessary to conduct in-depth research on the whole-chain division of the industrial chain from R&D and design, manufacturing to operation and service, fully identify the core post groups of each link, deeply analyze typical work tasks, competence elements and literacy requirements, clarify the scale of talent demand, competence level and quality requirements of each link, and form a complete post competence map of the industrial chain. This process cannot stay at the superficial correspondence of post names, but must go deep into the essence of post work, accurately grasp the comprehensive requirements of posts on knowledge, skills and literacy, ensure the precision of specialty setting, and avoid the dislocation phenomenon of “same name but different quality” between specialties and posts.

On this basis, a “core-support” specialty cluster structure is constructed to realize the full-link coverage of specialties to the industrial chain. Core specialties are set around the core links of the industrial chain, corresponding to the key post groups of the industrial chain, and undertake the task of cultivating core skilled talents. Support specialties are set around the supporting links to form a complementary and collaborative specialty matrix, which supports the talent cultivation of core specialties and covers the supporting posts of the industrial chain. In view of emerging fields and scarce posts in the industrial chain, it is necessary to add new specialties or specialty directions in a timely manner to fill the gap in talent supply and solve the problem of lagging talent supply in emerging fields. Each specialty in the cluster not only maintains a relatively independent cultivation direction to ensure the quality of core skill cultivation for each post, but also shares public basic resources and cross-specialty practical training platforms to form a joint force of collaborative education and jointly cultivate compound high-skilled talents.

At the same time, a dynamic adjustment mechanism of specialties driven by industrial demand is established to ensure that specialty construction resonates with industrial development at the same frequency. Keeping pace with the technological iteration and business format upgrading of the industrial chain, a regular research and judgment system for industrial demand is established. A research and judgment team composed of industry experts, enterprise technical backbones and college specialty leaders conducts regular industrial research, dynamically adjusts specialty directions

and optimizes cultivation orientation according to changes in post demands, so as to avoid specialty construction lagging behind industrial development.

Taking standard construction as the guide, professional teaching standards are jointly developed with industries and enterprises, and enterprise post standards are integrated into specialty norms to unify the quality benchmark of talent cultivation in the cluster, so as to guarantee the adaptability of specialties to the industry from the institutional level. The dynamic adjustment mechanism is the key to maintaining the vitality of specialty clusters, which can keep the specialty layout always following the pace of industrial development and realize the dynamic matching between talent supply and industrial demand.

3. Construction of Teaching Implementation System Based on Industrial Practice

The teaching system is the core carrier of high-skilled talent cultivation. Its goal is to break the barrier between theory and practice, and realize the precise docking between students' abilities and the high-skill requirements of posts with the typical work tasks of the whole industrial chain as the core. The implementation layer is the core of the three-layer model and directly determines the quality and effectiveness of talent cultivation.

Implement reverse curriculum design under the OBE concept to build a modular curriculum system. Taking the comprehensive competence requirements of core posts in the industrial chain as the final output goal, the knowledge, skills and literacy requirements for talent cultivation are sorted out reversely, and the curriculum system is constructed on this basis. Breaking the traditional disciplinary curriculum structure, teaching content is integrated with typical work tasks as the core to realize the one-to-one correspondence between curriculum content and post competence, so that what students learn is what posts need.

The curriculum system takes into account both professionalism and compoundness. It not only sets up core curriculum modules for each specialty direction to ensure the quality of special skill cultivation, but also sets up cross-specialty shared curriculum modules to cultivate students' whole-chain cognition and cross-post collaboration ability, so as to adapt to the demand for compound talents in the industrial chain. The modular curriculum system has strong flexibility, which can quickly adjust the curriculum content according to changes in industrial demand and maintain the timeliness and adaptability of the curriculum.

Implement project-based teaching with real projects as carriers to realize the education process of integration of theory and practice. Real production and operation projects of enterprises are introduced into the teaching process. Teaching is organized with the whole-process projects of the industrial chain as the carrier, and a school-enterprise dual-teacher teaching team is formed to guide students to participate in the whole process of project demand analysis, scheme design, implementation and operation, and achievement acceptance.

Students complete knowledge learning and skill training in

project practice, form complete post work ability, and realize the integration of theory and practice of “learning by doing, doing by learning”. Project setting follows the principle of from easy to difficult and from single to comprehensive, matches students’ ability growth stages, gradually transits from basic skill training projects to comprehensive production projects, and gradually improves students’ skill complexity and comprehensive task processing ability, so that students’ abilities grow step by step in project practice.

Build a full-scenario practical training platform with virtual-real symbiosis to solve the problem of scarce practical training resources in high-end industries. In view of the common pain points of high cost and high risk of practical training in high-end industries, all kinds of practical training resources online and offline, on and off campus are integrated to build a layered and progressive practical teaching system.

Digital technologies such as digital twin and virtual reality are fully used to build a virtual simulation practical training platform, which transforms high-risk and high-investment practical projects into repeatable training digital scenarios, reduces practical training costs, improves training efficiency, and allows students to practice core skills repeatedly. On-campus real-scenario practical training workshops are built to replicate the real working environment of enterprises, realize the docking between daily teaching and workplace standards, and carry out regular skill training. Off-campus practical training bases are set up relying on enterprise production sites, allowing students to experience practical ability in real production scenarios and improve post adaptability.

Through the complementary linkage of three scenarios: virtual simulation, on-campus workshops and enterprise sites, the whole ability growth process from basic skill training to comprehensive practice is covered, forming a practical education pattern of full-scenario tempering.

Deepen the competence tempering path of integration of posts, courses, competitions and certificates to strengthen students’ skill precision and comprehensive literacy. The standards of vocational skill grade certificates and the requirements of vocational skill competitions are integrated into the curriculum system and teaching content, so as to promote learning through competitions and practice through certificates, and improve the skill level and professional adaptability of talent cultivation.

The training logic of skill competitions is combined with the teaching process, and the high-precision skill requirements of competitions are transformed into daily teaching standards, so as to drive the overall improvement of teaching quality with high standards of competitions. The assessment content of vocational skill grade certificates is embedded in curriculum assessment to realize the integration of courses and certificates, so that students can obtain vocational skill certificates while completing curriculum learning, and enhance their professional adaptability and employment competitiveness.

The integration of posts, courses, competitions and certificates organically combines post requirements,

curriculum teaching, skill competitions and certificate assessment, forming a multi-dimensional competence tempering system to facilitate the cultivation of high-skilled talents.

4. Construction of Supportive Ecology with Collaboration among Government, Industry, Enterprises and Colleges

The guarantee layer is the support for the long-term operation of the cluster cultivation model. Its core is to build a governance system with collaboration of multiple subjects in the upper, middle and lower reaches of the industrial chain, form a full-cycle closed-loop collaborative education chain, realize the upgrading from “single-point school-enterprise cooperation” to “whole-chain industry-education collaboration”, and provide institutional guarantee and motivation support for cluster cultivation.

Build a multi-governance governance structure of industrial colleges to stimulate the endogenous motivation of enterprises to participate in education. Taking modern industrial colleges as the core carrier, a governance structure of “council system + dual chairperson system of school and enterprise” is established, which clarifies the rights and responsibilities of the four parties: government, industry, enterprises and colleges, and establishes a regular decision-making mechanism.

Through institutionalized structural design, enterprises are promoted from cooperative participants to co-governors of schooling, so that enterprises have the right to speak and make decisions in talent cultivation, and fundamentally stimulate the endogenous motivation of enterprises to participate in talent cultivation. The council regularly deliberates on major issues such as talent cultivation programs, resource allocation and cooperation projects, ensuring that the direction of cluster-based education is consistent with industrial demand, and coordinating resources of all parties to provide resource support for cluster cultivation.

The governance structure of industrial colleges is the organizational guarantee for multi-subject collaborative education, which can effectively solve the problems of loose and shallow school-enterprise cooperation.

Build a full-cycle closed-loop collaborative education chain to realize whole-process co-education between schools and enterprises. Relying on the platform of industrial colleges, industrial demand and enterprise resources are integrated into the whole cycle of talent cultivation: enrollment, cultivation, practical training, employment and development, breaking the drawbacks of traditional segmented education.

Starting from the enrollment link, enterprises participate in talent selection, clarify cultivation goals and employment directions, and realize enrollment as recruitment and entrance as enterprise entry. During the cultivation process, enterprises deeply participate in curriculum development, teaching implementation, practical training guidance and other links, and provide core resources such as teachers, projects and practical training venues to transform industrial resources into educational resources. In the employment stage, targeted post

docking is carried out to ensure precise employment of talents. After employment, the career development of graduates is continuously tracked, and the quality of talent cultivation is fed back to provide a basis for the optimization of cultivation programs.

The full-cycle collaborative education chain allows enterprises to deeply participate in all links of talent cultivation and realize the seamless docking between talent cultivation and industrial demand.

Design a step-by-step talent growth path following the law of professional ability development. Following the law of professional ability growth, a four-stage progressive cultivation path of “cognition - skill - practice - employment” is designed. Different teaching scenarios and practice carriers are matched for different stages to gradually realize the identity transformation from students to apprentices and then to high-skilled talents.

The junior stage focuses on professional cognition and basic skill consolidation, establishing professional cognition and consolidating professional foundation through industrial cognition courses and enterprise visits. The middle stage focuses on special skill strengthening and simulation training, and strengthens special skills through core skill courses and virtual simulation training. The senior stage focuses on enterprise post practice and employment adaptation, and experiences practical ability through post internship and real project practice to realize employment docking.

A segmented cultivation mode is adopted to reasonably arrange the time ratio of on-campus study and enterprise practice, so as to realize the step-by-step advancement of ability.

Establish a process evaluation system empowered by digitalization to realize the dynamic optimization of talent cultivation. Relying on the digital management platform, personal ability growth files are established for students, which dynamically record core indicators such as students' skill mastery, project performance and professional literacy, and comprehensively track the ability growth process of students.

A school-enterprise joint assessment and evaluation mechanism is implemented, combining process evaluation and summative evaluation. The evaluation subjects include school teachers, enterprise tutors and industry experts, and the evaluation content takes into account knowledge, skills and literacy, so as to comprehensively and objectively evaluate students' ability growth and ensure that the evaluation results can truly reflect the high-skill level of students.

The process evaluation system can not only provide a basis for students' step-by-step advancement, but also provide data support for teaching improvement, and promote the continuous improvement of teaching quality.

5. Internal Mechanism of Closed-Loop Operation of the Model

To ensure the effective linkage of the three-layer coupling

model, it is necessary to build a closed-loop operation mechanism running through the whole process, so as to realize the dynamic adaptation and continuous optimization of the model. The four mechanisms act on different levels respectively and jointly form a complete operation closed loop.

The dynamic transmission mechanism of industrial demand acts on the structural layer and is the core mechanism to ensure that the direction of talent cultivation keeps pace with industrial demand. A regular industrial demand research and judgment mechanism is established. Through industry associations and leading enterprises, the technological dynamics, post changes and talent demand information of the industrial chain are regularly collected, and transformed into the needs of goal adjustment and content optimization for talent cultivation, which are reversely transmitted to all links such as specialty setting, curriculum development and teaching implementation, forming a transmission chain of “industrial demand - cultivation adjustment - competence adaptation”, ensuring that talent cultivation always follows the pace of industrial development.

The collaborative research mechanism of school-enterprise standards acts on the implementation layer and is the core mechanism to ensure the docking between talent cultivation quality and post standards. A school-enterprise joint standard development mechanism is established. Around core norms such as professional teaching standards, curriculum standards, practical training standards and evaluation standards, they are jointly developed by school professional teachers, enterprise technical backbones and industry experts. Enterprise post operation specifications, technical quality standards and professional literacy requirements are fully integrated into the teaching standard system, realizing the seamless connection between teaching standards and post standards, and unifying the quality benchmark of talent cultivation in the cluster.

The two-way resource integration and sharing mechanism acts on the guarantee layer and is the core mechanism to ensure the resource supply for cluster cultivation. A two-way sharing mechanism of educational resources and industrial resources within the cluster is established. At the educational resource level, teachers, courses, practical training equipment and other resources of each specialty in the cluster are integrated to realize mutual employment of teachers, sharing of courses and sharing of equipment, and improve resource utilization efficiency. At the industrial resource level, enterprises' technology, venues, projects and other resources are opened up and transformed into teaching resources to be integrated into the cultivation process. Through two-way resource sharing, sufficient resource support is provided for cluster cultivation, and a win-win situation between schools and enterprises is realized.

The closed-loop quality evaluation and feedback mechanism runs through the three-layer system and is the core mechanism to ensure the continuous optimization of the model. A diversified talent cultivation quality evaluation and feedback mechanism is established. On the one hand, process evaluation of students' ability growth is carried out through school-enterprise joint assessment, and teaching arrangements are adjusted in a timely manner to realize the

dynamic optimization of the cultivation process. On the other hand, a graduate tracking survey and enterprise employment feedback system is established to regularly collect data such as graduates' employment quality, post competence and enterprise satisfaction, which are fed back to the front end of talent cultivation to promote the continuous optimization of cultivation programs and teaching content, forming a closed-loop improvement education mechanism.

6. Conclusion

The three-layer coupling model of high-skilled talent cluster cultivation, namely "structural layer, implementation layer and guarantee layer", is a systematic reconstruction of the traditional single specialty schooling model. Its core is to realize the all-round docking of specialty layout, teaching process and support system with industrial demand through the full embedding of industrial chain logic.

This model not only follows the education law of vocational education, but also conforms to the operation logic of the industrial chain. It ensures the dynamic adaptation of the system through four closed-loop operation mechanisms, and can effectively solve the structural contradiction of current high-skilled talent cultivation and improve the industrial adaptability of talent cultivation.

The three-layer coupling model provides a systematic solution for vocational education to align with the industrial chain. It has strong universality and can provide theoretical reference and framework for the cluster cultivation of high-skilled talents in different industrial fields.

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