Innovative Paths for Cultivating Application-Oriented Talents in Chemical Engineering from the Perspective of Industry-Education Integration

Yuhuan Zhang*

Hainan Vocational University of Science and Technology, Haikou, 571126, China
**Corresponding author: zhangyhhh@126.com*

Abstract: *With the trend of intrinsic safety in the chemical industry towards green manufacturing and intelligent operation, the old model of training based on disciplines has shown structural deficiencies in light of rapid technological changes. The reasons for applying the concept of industry-education integration in terms of the concept are divided into three parts in this paper: coupling mechanisms, competency structure and model deficiencies. Present the concept of organisational ecology and study the innovation of organisational form, modes of resource interaction and development paths for the integrated community. According to the idea of competence, the following three types of path innovation will be put forward: reform of the modular and flexible curriculum system, integration of the cultivation of engineering thinking and innovative ability, and construction of a full-cycle quality assurance and dynamic evaluation system. Research has indicated that the main reason for the integration of industry and education is the structural link between the industrial technology system and the disciplinary knowledge system. At present, there has been a move in the construction of the integration community from loose linkage to deep integration, and competency-based innovation in training pathways can meet the chemical industry's demand for interdisciplinary engineering talents.*

Keywords: *Industry-Education Integration, Application-Oriented Talents in Chemical Engineering, Training Model, Organisational Ecology, Competency-Based*

Introduction

As one of the representative processes of the process industry, the chemical industry is now changing technologically and shifting from unit operations to system integration, and from empirical control to intelligent management and control. Therefore, we need to improve the engineering cognition, process optimisation, safety awareness and green chemistry ideas of the practitioners. The first type of training model is based on disciplinary logic and has a simple linear hierarchy for its curriculum. The main type of teaching content is theoretical deduction, there is no systematic integrated training, and the assessment methods are not good at measuring high-level abilities such as engineering judgment and multi-objective optimisation decision-making. With the development of the digital industrial revolution, this model has shown deficiencies in updating knowledge and is not comprehensive enough in cultivating all kinds of abilities. First, this paper will present the coupling mechanism of industry-education integration; next, we will reconstruct the framework of core competencies; then, based on organisational ecology, we will outline the operating mechanism of the integration community; finally, according to the concept of competencies, we will propose an all-encompassing cultivation path.

1. The Logical Foundation of Industry-Education Integration and the Reconstruction of Elements in Chemical Engineering Talent Cultivation

1.1 The Coupling Mechanism and Value Dimensions of Industry-Education Integration

The first reason for combining industry and education in chemical engineering is that the system of industrial technology is closely linked to the system of disciplinary knowledge. As a typical representative of the process industry, the chemical industry has been developing technologically in line with the change from unit operations to system integration and from empirical control to intelligent management and control. Therefore, the system for cultivating talent should be freed from the old model of discipline. Based on the system theory, the main content of industry-education integration is to change the knowledge-production model from one based on disciplines to one based on scenarios. Now, real-world cases in chemical production, such as process optimisation, safety management and environmental regulations, have become the focus of knowledge organisation and innovation; they integrate the logic of academia with that of engineering to train talent in a more practical way[1].

For the coupling device to work properly, there should be agreement on values and coordination of goals among all parties. At the intersection of industry and education in the field of chemical engineering, they have both aimed to achieve the generative goals of engineering competence. Educational institutions aim to organise the systematic construction of cognitive structures, and industrial enterprises hope to enhance the efficiency of technical operation and problem-solving. The unification of value dimensions has increased the demands for safety, quality, etc., in domestic industrial engineering; technology research and development bases have been established, process innovation projects have been launched, and an isomorphic relationship between knowledge dissemination and technical inheritance at the value level has been created.

1.2 Deconstruction of the Core Competencies of Application-Oriented Talents in Chemical Engineering

The necessary qualities of application-oriented talents in chemical engineering vary according to different engineering fields and industries. With the development trend of inherent safety, green manufacturing and intelligent operation in the chemical industry, the core competencies of new-type chemical engineering talents can be divided into four parts: engineering cognitive ability, which is the systematic knowledge of chemical processes, internal correlations among process parameters and the mechanisms of material and energy transformation in unit operations; process optimisation capability, referring to the systematic thinking on technical improvements to production processes, enhancement of energy efficiency and improvement in resource utilisation efficiency; safety ethics awareness, which covers the systematic identification of risks in chemical processes, construction of emergency plans and internalisation of a safety culture; and green chemistry thinking, which takes the form of a full life-cycle environmentally friendly philosophy that includes source reduction and process control as well as end-of-pipe treatment.

The four attributes of competencies are organised in an organised way and have hierarchy and interdependence. Engineering cognitive ability is the foundation of the competency system and determines how well one can grasp the problems in complex chemical engineering. Optimisation of the process and application of technology is to solve practical problems in life for the people. The top two are the consciousness of safety ethics and green chemistry thinking; together, they help people consider all the aims of efficiency, safety and environmental protection in their technical selections. As shown in the structure above, there are many different and frequently changing demands on talents in the field of chemical engineering. In addition to having a good foundation in engineering and operation, people also need to be eager to learn continuously and adapt to the rapid changes in the world brought about by new technologies.

1.3 Structural Limitations of the Traditional Training Model and the Need for Reform

The old training model for application-oriented talents in chemical engineering needs to be organised better by the organisation. They are mainly a curriculum system organised according to disciplinary logic rather than engineering logic, and in terms of teaching content, there is a focus on the theoretical deduction of unit operations and a reduction in systematic integration training. The old way of spreading knowledge has been divided into three levels: basic courses, specialized basic courses and specialized courses; although it covers all aspects, it is too rigid and cannot keep up with the rapid changes in technology in recent years. Another problem is that the traditional model assumes that chemical processes are ideal and can be expressed in simple mathematical language; it does not take into account all the non-ideal conditions of actual production, such as equipment characteristics and differences in raw material quality. As a result, the cognitive system of the students cannot be used to solve problems in advanced engineering[2].

Structural problems in the old model can also be observed in the one-dimensional nature of its evaluation system. The main components of the summative assessment are course examinations, which can only test students' knowledge recall and application of formulas; they are not very effective in assessing higher-order thinking skills such as engineering judgment, fault diagnosis and multi-objective optimisation decision-making. This kind of evaluation will make the students focus only on grades and lose the ability to think like engineers or be creative. With the demand for role-capability reconstruction in light of the digital transformation of the chemical industry, the traditional training model has structural conflicts with the development of the industry in terms of the speed of knowledge updates, scope of capability cultivation and quality assessment standards. Therefore, the organisation of talent cultivation, the contents of the curriculum and the forms of assessment will all need to be reformed systematically.

2. Construction Mechanism of the Industry-Education Integration Community from the Perspective of Organizational Ecology

2.1 Innovation in the Organizational Form of Integration with the Participation of Multiple Subjects

According to the ecological theory of organisations, the construction of the industry-education integration community in the chemical engineering field can be viewed as a whole-picture restructuring of the organisational forms of many subjects. In the traditional model, chemical engineering colleges and enterprises have a loose cooperative relationship, and there are also considerable differences in their organisational structure, operating logic and values; thus, they have been developing independently in separate ecological niches. The new form of organisation for integration hopes to solve the problem of division in structure and build mutually beneficial organisations that can achieve both the goals of technological research and development and talent cultivation. Cross-embed the organisation structure and resources of the industrial side, such as technology research and development centres, process laboratories and pilot-scale platforms, with those of teaching institutions and research institutes in the educational sector to form an integrated carrier that combines the functions of teaching, research and development and technical service.

Given the characteristics of the chemical industry, many integrated organisational forms have been set up. Chemical processes are continuous, systematic and safety-critical, so the construction of an integrated organisation should also consider the constraints on talent cultivation imposed by the need to maintain the integrity of the process flow. Compared with the discrete manufacturing industry, the transmission of technical knowledge and the development of capabilities in the field of chemical engineering require an understanding of and operation of the entire production system. Therefore, the integrated organisational form should be based on the actual process units or production equipment, and an organisational environment that is suitable for real production processes should be created. In accordance with the concept of the technological system's integrity, the organisation has achieved the aim of changing the function of the integrated unit from that of a supporting teaching institution to that of a centre for technological development and capability building.

2.2 Resource Interaction and Element Flow Mechanism Guided by Integration

At the core of the resource interaction mechanism under the guidance of integration is to open up channels for the flow of elements between the chemical industry system and the education system, thus achieving joint enhancement of core resources such as knowledge, technology, equipment and talent. The tacit knowledge of technical knowledge in the field of chemical engineering is particularly pronounced, and a large number of process know-how, fault diagnosis experience and optimisation strategies cannot be effectively transmitted through written words alone. Therefore, the absorption and spread will be based on the actual engineering case and instructions. Based on the above reasons, the mechanism of resource interaction will be constructed according to the actual project carriers. Therefore, the technical staff can collect process data and operational experience during their work, turn this into knowledge resources, and then apply it in teaching. At the same time, we can see from the above that the results of theoretical research and experimental data in the education sector are also used to improve industrial technology in a closed-loop manner[3].

Institutions and carriers will organise the operation of the element flow mechanism. The Scale of the material resource dimension is that chemical equipment and experimental instruments have a high investment cost, are highly specialised, and have high maintenance fees. The division of costs and the allocation of the right to use the shared equipment resource should be stipulated in the contract, and the rights and obligations of all parties in terms of investment in resources and sharing of benefits need to be clarified. Given the size of the human resources, the movement of technical talent should be organised flexibly and cover both entry and exit. Industrial technical experts will also be involved in the development of the curriculum and engineering guidance, and faculty members from educational institutions will take part in the on-site production activities, technological problem-solving and process improvement. The two-way flow mode can help to solve the problem of human resources shortage at the enterprise level, and at the same time, new ideas and technological concepts from leading industrial enterprises can be introduced into the education system for talent cultivation.

2.3 The Operating Logic and Evolution Path of the Industry-Education Integration Community

The operating mode of the industry-education integration community is to coordinate and integrate the various goals of all parties concerned. Organizations in the chemical industry hope to strengthen their technological competitiveness and achieve economic benefits, and the main problems for educational institutions are the quality of talent cultivation and the level of disciplinary education. There is an end to life, and there is also death. To promote good governance of the community, a coordination mechanism will be established to achieve multiple goals and have all parties cooperate to create value through integration. Organisational terms refer to the basis of the coordination mechanism, and the common goal for all areas in the community will be to build construction engineering capacity. High-quality technical talents with systems engineering skills can be obtained by participating in the talent cultivation program of the industrial side, and the educational institution will adjust the teaching content in coordination with the actual needs of the industry. Therefore, the two parties are interdependent and need to work together to build the chain of capabilities.

In terms of the path of development, the construction and progress of the industry-education integration community have shown phased characteristics and have progressed from loose linkage to deep integration. At first, many people formed short-term cooperative networks for particular projects or resource sharing, and although they worked together to some extent, they retained the autonomy of their original organisations. With closer cooperation among the members and the formation of trust, the community has begun to show signs of organisational integration. Organizational boundaries are starting to break down, and it is becoming more common to share staff and resources and jointly develop standards. In the later stages of development, the community will build an integrated carrier in cooperation with a legal person or quasi-organisation to achieve good synergy among the standards for talent cultivation, the direction of research and development for technology, and industrial strategic needs. As a high-tech industry, the chemical industry has also been developing in an integrated manner, so only by including it in the organisational structure can we meet the demand for cultivating engineering talents in a systematic engineering environment effectively[4].

3. Innovation in the Training Pathway for Chemical Engineering Talents Based on Competency Theory

3.1 Modular and Flexible Reconstruction of the Curriculum System

The construction of the curriculum system for application-oriented talents in chemical engineering should be based on the generative principle of competence, move away from the traditional discipline-oriented organisation of the curriculum, and build a modular structure around units of engineering competence. Given the characteristics of the process flow in the chemical industry, one should learn them step by step and move from the concept of unit operations to the optimisation of system integration. According to the size of the ability to form functional units, the content of the curriculum is organised in modules, and these include basic process modules, process control modules, safety and environmental protection modules, and intelligent chemical engineering modules. Each module contains the theoretical knowledge, technical foundation and engineering norms of the corresponding courses to help students build an organised system of knowledge and skills in a particular area of engineering after completing that course, thus achieving good alignment among the components of knowledge and competence objectives.

Design of a Flexible Mechanism to Improve the Adaptability of the Curriculum System in the Chemical Industry to Changes in Technology. With the continuous addition of new materials, new processes and new equipment, the flexible curriculum system has taken the form of three tiers: "core required modules", "directional elective modules" and "frontier dynamic modules"; thus, space has been made for the introduction of new technological fields while maintaining the stability of the core knowledge system in chemical engineering. A flexible Design for the curriculum schedule can allow students to choose different learning paths and speeds in the following courses according to their individual development needs and ability reserves after mastering the basic courses, moving away from the old uniform method of education and adopting personalised learning[5].

3.2 The Integrated Cultivation Paradigm of Engineering Thinking and Innovation Ability

Together, promote engineering thinking and the spirit of innovation; build a deep-learning model to solve engineering problems at the teaching level, and then use it. Engineering problems in the field of chemical engineering are generally multiparametric, have many constraints and are high-risk. The basic idea of the integrated cultivation model is to take the unstructured problems that arise in actual engineering construction as teaching materials and then lead students to solve these problems in order to cultivate both the technical rationality of engineering thinking and the breakthrough quality of innovative ability. A series of project-based learning activities will be based on the whole chemical process flow, and at various levels of difficulty, a set of engineering problems will be created, such as optimisation of unit equipment operation and section interlocking control, organisation of workshop production, and design of plant systems. Therefore, by providing students with progressively difficult problems, they will be able to accumulate their engineering knowledge gradually.

Cultivation of innovative ability can be demonstrated by the higher-order thinking activities of students in the process of solving engineering problems. Technological innovation in the field of chemical engineering includes changes in production routes, optimisation of the reaction environment, improvement of separation technology, new safety control measures, etc. In short, it is the reconstruction and development of the original engineering knowledge. There are open-ended engineering problems in the integrated cultivation model, and students need to find all sorts of technical solutions under the given constraints, then compare and optimise these solutions based on many indices, such as techno-economic analysis, safety risk assessment, environmental impact assessment, etc. The arrangement of instruction above can help students develop all links in the cognitive chain of innovation—that is, problem recognition, solution design, technical verification, effect assessment—during the completion of engineering tasks, and thus promote the integration of training in engineering thinking and cultivation of innovative ability.

3.3 The Full-Cycle Quality Assurance and Dynamic Evaluation Mechanism

The whole process of quality assurance should expand the scope of quality supervision from the end of cultivation to all times during cultivation, form a complete closed-loop system, and cover the entry point of enrollment, the cultivation process, and the exit point of graduation. The characteristics of application-oriented talent cultivation in chemical engineering can be seen in the three areas of knowledge acquisition, skill attainment and competency formation. The generation of capabilities in the above areas will have different time periods and development paths. Given the special attributes of chemical engineering, many links have been added to observe the development of quality assurance. The foundation of the theoretical study is the assessment of knowledge integration; the evaluation of skill proficiency is carried out during unit operation training; and the evaluation of project completion is performed at the general engineering practice stage, so a staged and multi-dimensional quality supervision system has been established.

The basis of the dynamic assessment system is to move from cumulative judgment to continuous observation of development, and a new model of evaluation will be built based on the collection of competency evidence. Dynamic assessment has added many kinds of tests, such as portfolio assessments, performance evaluations and peer assessments, to collect systematic evidence of students' achievements in all sorts of engineering tasks and create an individual profile that shows their development in various areas. The first kind of evaluation is more suitable for studying the high-level cognitive functions in chemical engineering, such as engineering judgment and the ability to recognize safety risks and make decisions under different circumstances; therefore, to cultivate such qualities, observation and evaluation of behaviour in real or simulated engineering environments need to be carried out. Feedback on the results of the assessment can help learners know their current level in the development of abilities early on, adjust their study plans and direction of effort, and thus form a good feedback loop between assessment and learning.

Conclusion

Another way to foster a model of application-oriented talents in chemical engineering is to integrate industry and education. At the level of logical foundation, this paper believes that the core of industry-education integration is to change the mode of knowledge production from one driven by disciplines to one driven by scenarios. Convergence of values in the industry and education is shown by their joint pursuit of the generative principles of engineering competence. The four basic qualities of application-oriented talents in chemical engineering should be engineering cognitive ability, process optimisation ability, safety ethics consciousness and green chemistry thinking. Organised correction of the structural deficiency in the old training model of curriculum construction, knowledge dissemination and assessment focus is needed. At the level of organisational ecology, this paper believes that the construction of the integration community should move away from the old model of loose cooperation and form a symbiotic organisational unit focused on the two goals of technological research and development and talent cultivation. Resource interaction has promoted the joint development of knowledge, technology, equipment and talent in the community, and as a result, it has gone from loose linkage to structural integration and finally to deep synergy. The first type of innovation in educational paths presented here is the competency-oriented trinity training model, which has three parts: modular and flexible reconstruction of the curriculum system, integrated cultivation paradigm of engineering thinking and innovative ability, and full-cycle quality assurance and dynamic evaluation mechanism. Further research can be carried out on the differences in the adaptation of integration models for all kinds of chemical engineering colleges and industrial enterprises, investigate quantitative evaluation methods for the operational performance of the integration community, and explore in depth the reasons why intelligent technologies are changing the model of chemical engineering talent training.

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