https://doi.org/10.62836/jissh.v2i1.396

Global Science Publishing

JISSH

Journal of Integrated Social Sciences and Humanities

https://ojs.sgsci.org/journals/jissh

Article

Reforming Graduate Curriculum Systems through Industry-Education Integration: A Socially Responsive Approach to Innovation Capacity Development

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Abstract: This study explores a socially responsive framework for reforming professional graduate curriculum systems by aligning them with dynamic industrial changes and innovation demands. Grounded in educational ecology and competency-based theory, the proposed model includes a modular structure emphasizing demand identification, collaborative development, and system adaptation. Beyond improving professional education quality, the framework addresses broader social imperatives—bridging gaps between higher education and labor market demands, promoting equitable access to innovation-oriented training, and supporting the co-evolution of educational institutions and regional socio-economic systems. This research contributes to ongoing discourse on how curriculum reforms can better serve both individual development and societal transformation.

Keywords: professional graduate education; curriculum reform; industry-education integration; social responsiveness; educational policy; regional development

1. Introduction

Professional degree, in contrast to academic degrees, is a type of degree that is practice-oriented, emphasizing practice and application. It has clear differences from academic degrees in terms of training objectives. The aim is to cultivate high-level specialized talents who have a solid theoretical foundation and are capable of meeting the practical needs of specific industries or professions [1]. President Xi Jinping stresses the importance of promoting the integration of science education with industry and enhancing the practical and innovative abilities of graduate students to provide more solid talent support for building a socialist modern power [2]. The intelligent transformation of industries triggered by the Fourth Industrial Revolution has fundamentally restructured the capability spectrum required for professional degree talents.

Under the context of technological convergence, job capability requirements show three major shifts: from single-technology operations to interdisciplinary system integration, from linear knowledge application to nonlinear problem-solving, and from static skill reserves to dynamic adaptability. This transformation poses threefold challenges to traditional curriculum systems: the lagging nature of knowledge supply fails to match the speed of technological iteration; the closed nature of practical teaching cannot adapt to open innovation scenarios; and the academically oriented evaluation system deviates from professional competency standards.

From the perspective of educational ecology, professional degree courses need to establish dynamic response mechanisms. Its theoretical core consists of three levels: the demand perception layer analyzes

Received: 28 April 2025; Accepted: 12 May 2025.

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industrial technology maps to transform emerging technical standards into a matrix of capability elements; the curriculum mapping layer adopts modular design principles to establish topological relationships between capability units and course modules; the feedback adjustment layer relies on big data technology to form a closed-loop system for monitoring educational quality and optimizing courses. Within this framework, the value of the CDIO (Conceive-Design-Implement-Operate) model lies in embedding the entire cycle of engineering education into industry innovation processes, achieving synchronous evolution of knowledge construction and capability development through learning by doing (as shown in Figure 1).

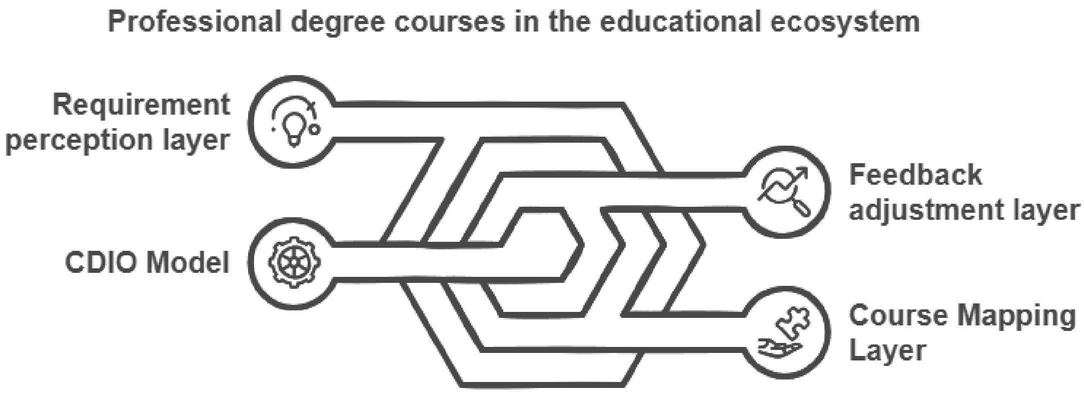

Figure 1. Dynamic response mechanism from the perspective of educational ecology.

The analysis of industrial technology maps is the core of demand perception. This process requires integrating technology readiness level curves with value chain analysis to identify technical bottlenecks and capability gaps in key areas. For example, in the field of intelligent manufacturing, the convergence of technologies such as industrial internet, digital twins, and autonomous decision-making systems demands that practitioners possess end-to-end capabilities ranging from data acquisition to intelligent optimization. Traditional curriculum systems often limit instruction to single technical modules, lacking the cultivation of system integration capabilities.

Therefore, curriculum design should incorporate systems engineering theory to build a technology chain mapping model that covers “sensing—analysis—decision-making—execution”, ensuring a one-to-one correspondence between course modules and industrial technology nodes.

The construction of the feedback adjustment layer relies on the application of educational data mining techniques. By collecting data on learners’ mastery of knowledge, engagement in practical activities, and career development trajectories, a dynamic evaluation model of course effectiveness can be established. For instance, inferring course weights based on the technical requirements of graduates’ job placements allows for the optimization of teaching resource allocation for core competency modules. In addition, a triggering mechanism for curriculum updates must be established; when the growth rate of industrial demand in a certain technological area exceeds a predefined threshold, the curriculum revision process should be automatically initiated, ensuring the agility of educational supply.

2. Methods

2.1. Innovative Path of Industry Education Integration Mechanism

The essence of industry education integration is the collaborative evolution of the education system and the industrial system, which requires breaking through the surface interaction of traditional school enterprise cooperation and building an institutionalized mechanism for resource exchange and value co creation. Three factors, namely internal factors of the subject, coupling factors of both parties, and external environmental factors, have a significant impact on the overall choice of industry education integration mode in applied undergraduate colleges [3]. The theory of coevolution states that the deep coupling between educational institutions and industrial organizations requires three conditions: consistency of the objective function, complementarity of resource endowments, and balance of benefit distribution. This requires the establishment of a "double helix" fusion model: the education chain outputs intellectual capital to the industrial system through curriculum development and teacher sharing, while the industrial chain injects innovative potential into the education system through technology feedback and scenario supply. The construction of dynamic adjustment mechanism needs to follow the evolutionary path of "demand pull capability mapping feedback iteration". At the operational level, the Delphi method can be introduced for industry demand forecasting, and expert systems can be used to identify key technology areas and capability gaps for the next 3–5 years; Establish a capability factor weight model using Analytic Hierarchy Process to guide the priority allocation of course modules; Based on educational data mining technology, real-time tracking of graduates' career development trajectory, forming quantitative evaluation indicators for course effectiveness. Policy design should focus on establishing incentive compatible mechanisms, including tax leverage to regulate the proportion of school enterprise investment, legal protection for intellectual property sharing systems, and the construction of cross departmental collaborative governance frameworks.

The core of institutional innovation lies in building a governance structure for school enterprise collaboration. The practice of mixed ownership industry colleges has shown that through equity distribution and decision-making power sharing, the contradiction between educational public welfare and industrial profitability can be effectively balanced. For example, schools provide faculty and basic research resources, enterprises invest in equipment and market data, and both parties jointly establish a management committee to jointly develop talent development plans. In addition, a risk sharing mechanism needs to be established to constrain the performance of both parties through a "betting agreement" – if the enterprise fails to provide the promised practical positions, it needs to compensate for the education costs; If the school fails to achieve the training objectives, the cooperation terms need to be adjusted.

Breakthroughs at the policy level need to focus on three aspects: first, legislative protection to clarify the responsibilities and rights of enterprises in professional degree education; The second is financial support, establishing a special fund for the integration of industry and education, and providing tax credits to enterprises that deeply participate in school enterprise cooperation; The third is to evaluate the reform and incorporate the contribution of industries into the performance evaluation system of universities. For example, the success of Germany's "dual system" education is due to the mandatory provisions of the Vocational Education Law on the obligation of enterprise participation, as well as the full supervision of education standards by industry associations. These experiences provide important references for China to build a localized system of industry education integration

2.2. Modular Curriculum and Innovation in Practical Teaching

Modular course design should follow the development law of "T-shaped ability", vertically construct a three-level knowledge ladder of "basic theory, core technology, frontier exploration", and horizontally design interdisciplinary course clusters [4]. Based on constructivist learning theory, the connection of course modules needs to meet the principle of progressive complexity: basic modules focus on conceptual cognition and tool mastery, core modules strengthen technical integration and engineering implementation, and expanded modules cultivate systematic thinking and innovative breakthrough abilities. In the field of biomedicine, a modular chain of "molecular biology foundation drug design technology clinical translational innovation" can be formed, with each module embedded with soft skills training elements such as ethical decision-making and project management.

For universities, emphasis should be placed on strengthening the cultivation of practical abilities such as self-learning, information acquisition, observation and analysis, experimental research, expression and communication, and communication and cooperation skills among college students. The innovation of the practical teaching system requires breakthroughs in three dimensions: in the spatial dimension, constructing a hybrid practical scenario of "virtual simulation engineering center industrial base"; In terms of time dimension, a spiral ability advancement path of "cognitive internship project training on-the-job innovation" is adopted; In terms of methodology, implementing project-based learning (PBL) based on real problems, through the full process training of “problem definition scheme design prototype development iterative optimization”, cultivates design thinking and engineering innovation ability. The focus of quality control is to establish a visual evaluation system for the practical process, use digital twin technology to record operation trajectories, and analyze learners’ ability growth curves through multi-source data analysis (as shown in Figure 2).

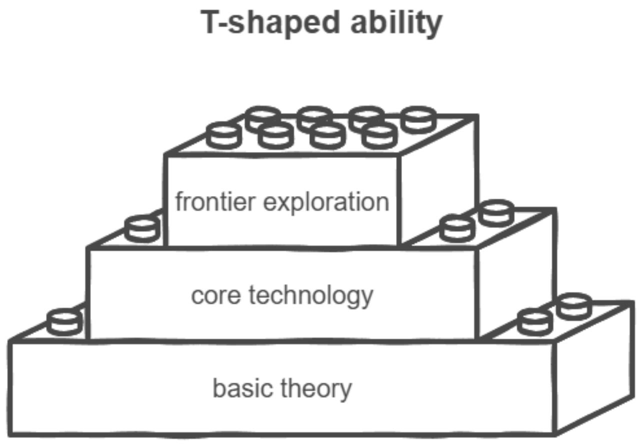

Figure 2. The ladder of three-level knowledge.

Interdisciplinary integration is the core challenge of modular design. It is necessary to introduce the “knowledge graph” technology to construct a semantic correlation network between disciplines. For example, in the development of the “Intelligent Transportation System” course, knowledge nodes from computer science, civil engineering, and urban planning are integrated to form an interdisciplinary link of “data collection algorithm optimization infrastructure design”. In addition, modular courses need to be embedded with an “innovation scaffold” design, which provides learners with phased support tools: standardized templates are provided in the primary stage, some design parameters are open in the intermediate stage, and the advanced stage requires independent definition of problem boundaries. This design not only lowers the learning threshold but also preserves innovation space. The quality assurance of practical teaching needs to rely on the “dual closed-loop” control model. The inner loop focuses on the teaching process and diagnoses ability deficiencies through real-time data collection, such as experimental operation records and project progress reports; External loop pays attention to social feedback, regularly collects evaluations of graduates’ abilities from enterprises, and optimizes practical content in reverse.

2.3. Reconstruction of Evaluation System and Teacher Capability

The reform of university teaching in our country is facing a triple institutional gap of regulatory, normative, and educational reform culture [5]. The evaluation paradigm of professional degree education needs to shift from “knowledge storage” to “ability release”. Based on the competency model, construct a five dimensional evaluation system that includes technical achievement, innovation breakthrough, team contribution rate, engineering standardization, and career development potential. At the methodological level, it is necessary to integrate formative evaluation and summative evaluation, use portfolio evaluation method to record the learning process, and introduce situational assessment to simulate real work challenges. The diversification of evaluation subjects requires the establishment of a tripartite collaborative mechanism consisting of enterprise mentors, academic mentors, and peer reviewers. The evaluation weight of enterprise mentors should not be less than 40%, with a focus on knowledge transfer and problem-solving effectiveness.

The construction of a competency model needs to follow the “iceberg theory”, which evaluates technical operations and output at the explicit level, and explores critical thinking and professional ethics at the implicit level. For example, in engineering ethics evaluation, a dilemma scenario simulation test can be designed to observe learners’ trade-off decisions between cost constraints, safety standards, and technological innovation. The evaluation of archive bags needs to break through traditional paper carriers and adopt blockchain technology to store learning trajectories, ensuring the immutability and traceability of evaluation data. In addition, dynamic weighting algorithms need to be developed to adjust the weight of evaluation dimensions according to different learning stages – the entry-level stage focuses on skill mastery, the advanced stage emphasizes innovation, and the graduation stage focuses on career development potential.

The ability reconstruction of the teaching staff should follow the “dual teacher” development path, and its ability matrix includes four dimensions: academic research ability, engineering practice ability, teaching design ability, and industry insight. The teacher development support system should include three pillars: establishing a system of mutual employment between school and enterprise personnel, implementing “academic leave” to support teachers’ participation in enterprise technology research and development; Establish standards for teacher engineering competency certification and include industry project experience as a condition for professional title evaluation; Develop a digital platform for teacher professional development, providing continuing education courses in fields such as intelligent manufacturing and big data analysis. Institutional innovation needs to focus on solving the dilemma of “academic drift”, and balance the value weight of scientific research output and teaching innovation through the reconstruction of performance evaluation indicators. The cultivation of “dual teacher” teachers requires the construction of a “three-stage” development model: in the primary stage, familiarizing oneself with industry processes through enterprise internships, in the intermediate stage, participating in industry university research projects to accumulate engineering experience, and in the advanced stage, serving as enterprise consultants to deepen industry insights. For example, the German University of Applied Sciences (FH) requires teachers to practice in companies for six months every five years, otherwise they cannot be promoted to professor. In addition, it is necessary to establish a digital portrait of teacher competence, analyze teaching feedback, scientific research achievements, and engineering practice data through natural language processing (NLP), and generate personalized development suggestions.

3. Results

School Enterprise Cooperation Model and Policy Guarantee

School enterprise co construction courses generally have three modes: university led, enterprise led, and university enterprise collaborative [6]. The setting of course objectives is the initial stage of constructing a curriculum system, which not only needs to meet the standards of talent cultivation, but also needs to consider the needs of society [7]. The construction of a collaborative innovation community between schools and enterprises needs to go beyond the traditional resource exchange model and evolve towards a value co creation paradigm. Based on ecosystem theory, a “four chain integration” mechanism should be established: the education chain outputs human capital, the industry chain provides innovative scenarios, the innovation chain incubates technological achievements, and the policy chain guarantees institutional supply. In terms of cooperation models, contractual relationships such as “R&D outsourcing”, “risk sharing”, and “intellectual property sharing” can be explored. Among them, the “bet agreement” model can effectively incentivize both parties’ investment intensity – universities promise the quality of talent cultivation, enterprises guarantee the intensity of resource investment, and compensation mechanisms are activated when the goals are not achieved.

The implementation of the “four chain integration” needs to rely on regional industry education consortia. For example, the Yangtze River Delta Intelligent Manufacturing Industry Education Alliance integrates resources from universities, enterprises, and governments to establish an integrated platform of “technology research and development talent cultivation industrial application”. Its core mechanism includes: co building and sharing training bases, jointly applying for major scientific research projects, and collaboratively formulating industry skill standards. This type of alliance can solve the problem of fragmented cooperation between individual schools and enterprises, achieving economies of scale and collaborative innovation. In addition, it is necessary to construct an intellectual property allocation matrix to clarify the ownership of basic research results to universities, the sharing of application development results, and the proportional distribution of commercial transformation benefits, in order to resolve cooperation frictions at the institutional level (as shown in Figure 3).

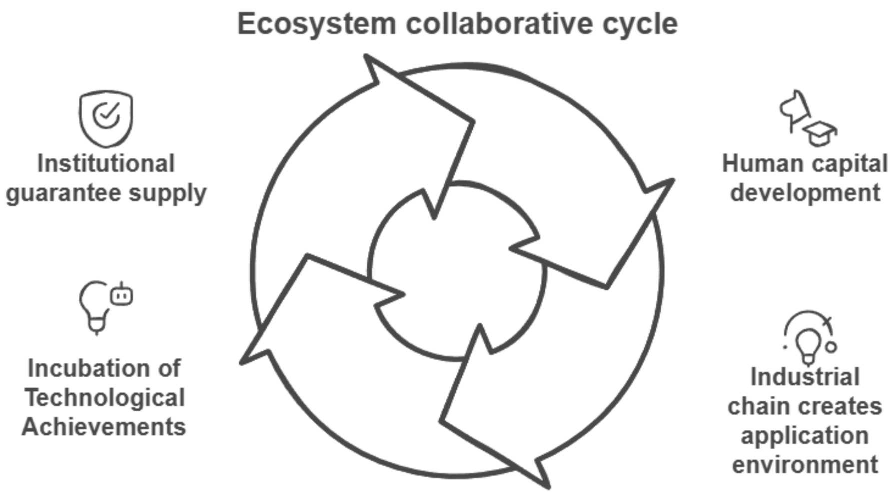

Figure 3. Four chain fusion mechanism.

The improvement of the policy system needs to focus on three levels: establishing a legislative framework for the integration of industry and education at the macro level, clarifying the rights and obligations of both schools and enterprises; Constructing regional industry education consortia at the meso level to achieve spatial agglomeration of educational and industrial resources; Innovate the educational system at the micro level and pilot mixed ownership industrial colleges. Especially, it is necessary to establish a dynamic adjustment mechanism for professional degree authorization points, construct a quantitative evaluation model that includes industry demand index, employment quality index, and course update rate, and implement an exit mechanism for majors that have ranked last in the evaluation for three consecutive years.

The key to legislative breakthroughs lies in defining the educational responsibilities of enterprises. You can refer to the French Apprenticeship Tax Law, which stipulates that enterprises above a certain scale must invest a certain proportion of their turnover in vocational education, otherwise they must pay special compensation. At the same time, it is necessary to establish a credit rating system for the integration of industry and education, and provide incentives such as government procurement priority and financing convenience to enterprises that actively participate in school enterprise cooperation. With the steady progress of China's "Double First Class" construction work, graduate education has entered a stage of connotative development [8]. At the university level, the contribution of industrial services should be included in the evaluation indicators of the "Double First Class" construction, promoting the shift of educational value orientation from academic paper orientation to industry demand response.

4. Discussion

The prominent feature of contemporary education is the continuous changes in educational forms and technologies. Monitoring, as a tool for evaluating educational quality and implementing the "baton" of quality education, must quickly respond to the constantly changing learning and evaluation information ecosystem [9]. The intelligent transformation of the education quality monitoring system needs to rely on education big data technology. By constructing a full process management system of "data collection cleaning modeling visualization", key indicators such as course implementation effectiveness, teacher competence status, and school enterprise cooperation efficiency can be tracked in real time. The application of machine learning algorithms can achieve three levels of early warning: demand warning (predicting future talent gaps), quality warning (identifying course implementation deviations), and development warning (evaluating the professional lifecycle). The introduction of blockchain technology can ensure the immutability of industry participation data and provide technical support for quality traceability.

Data collection needs to cover the entire lifecycle: analyzing the knowledge structure of students during the enrollment stage, monitoring learning behavior patterns during the teaching stage, and tracking career development trajectories during the employment stage. For example, through eye tracking and gesture recognition technology, students' attention distribution and proficiency in virtual simulation experiments can be analyzed; Using natural language processing (NLP) to analyze comments from corporate mentors and extract key word frequencies for innovation capabilities. In the modeling phase, a hybrid model architecture should be adopted, combining supervised learning (such as logistic regression for predicting employment quality) with unsupervised learning (such as clustering analysis for course module correlation) to enhance the interpretability and prediction accuracy of the monitoring system.

The construction of sustainable development mechanisms requires attention to the self generating function of educational ecology. By establishing a special fund for the integration of industry and education, we aim to attract social capital to participate in educational investment; Establish a "three-three system" distribution model for the transformation of achievements and benefits (schools, departments, and individuals each account for one-third), and stimulate the innovation motivation of teachers and students; Build an alumni network ecosystem and form a virtuous cycle of "talent cultivation career development resource feedback". In terms of internationalization, it is necessary to align with international engineering education standards such as the Washington Accord, establish a professional degree certification system with Chinese characteristics, and enhance the discourse power of global talent competition.

The operation of special funds can adopt the "parent fund & sub fund" model: the parent fund is funded by the government and is responsible for strategic direction control; The sub fund is managed by corporate or social capital and focuses on investing in specific areas. For example, a certain new energy industry education fund focuses on investing in hydrogen energy technology research and development and talent cultivation, with 20% of its profits going back to education projects. The activation of alumni networks requires the construction of a digital twin platform, connecting students and graduates through virtual communities to achieve experience sharing, project collaboration, and donation guidance. In addition, it is necessary to establish an international industry education alliance, promote credit recognition, teacher recruitment, and joint degree programs, and enhance the global influence of China's professional degree education.

5. Conclusions

The construction of a professional degree curriculum system oriented towards industry demand and innovation capability cultivation is essentially an evolutionary process of the education ecosystem adapting to the technological and economic paradigm. The study proposes to solve the supply-demand mismatch contradiction through a dynamic response mechanism, achieve structured upgrading of knowledge capabilities through modular reconstruction, and build an education industry community with a shared future through collaborative education ecology. Future research needs to deepen the empowerment of artificial intelligence in personalized course customization, the construction of a global industry education integration standard system, and pay attention to path dependence issues in institutional changes, providing sustained theoretical support for the high-quality development of professional degree education

Funding

This research is funded by Henan Province Graduate Education Reform and Quality Improvement Project (Grant NO. YJS2025XQLH10). Funded by Research and Practice Project on Higher Education Teaching Reform in Henan Province (Graduate Education Category) (Grant NO. 2023SJGLX150Y).

Author Contributions

P. Q. conceived and designed the study. S. Z. collected the data, while Y. D. wrote the initial draft, and both authors contributed to the final manuscript. All authors have read and agreed to the published version of the manuscript.

Institutional Review Board Statement

Not applicable.

Informed Consent Statement

Written informed consent was obtained from all participants prior to their participation in the study. Participants were informed about the purpose of the study, the procedures involved, and their rights to confidentiality and voluntary withdrawal.

Data Availability Statement

Not applicable.

Conflicts of Interest

The authors declare no conflict of interest.

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