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Research on Cultivation of Supply Chain Collaborative Management Competency for Engineering Management Majors Under Digital Background

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Abstract. At present, digital transformation, intelligent construction and the restructuring of engineering supply chains are changing the form of engineering project management, promoting its transformation from single-subject control to multi-subject collaborative governance. In view of the shortcomings in the cultivation of engineering management majors in terms of supply chain collaboration, digital platform application, data-driven decision-making and cross-organizational communication, this paper constructs a D-KCJP five-element coupled competency cultivation model, which integrates digital context, knowledge graph, competency system, job tasks and curriculum pathways, and forms a cultivation logic of "demand traction — graph support — competency transformation — job anchoring — curriculum implementation — evaluation feedback". This paper further proposes reform paths covering knowledge graph, six-dimensional competency framework, curriculum system optimization, job mapping and implementation guarantee, so as to provide reference for the cultivation of inter-disciplinary talents in engineering management.

Keywords: Engineering Management, Supply Chain Collaboration, Digital Transformation, Knowledge Graph, Competency Cultivation

1. Introduction

With the embedding of technologies such as BIM, Internet of Things, big data, artificial intelligence and cloud collaboration platforms into the whole process of engineering construction, the organization mode, resource allocation mode and management decision-making mode of engineering projects have undergone profound changes. Engineering management is no longer limited to schedule, cost and quality control within the construction site, but has become a complex supply chain collaboration issue running through investment decision-making, design collaboration, procurement and supply, construction organization, operation and maintenance delivery and other links [1, 2].

Traditional engineering management education is usually carried out in modules such as engineering economics, engineering project management, construction organization, engineering cost and contract management, with clear knowledge boundaries but insufficient comprehensive linkage. Digital engineering projects require engineering management personnel to not only master

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the basic principles of project management, but also understand the supply chain structure, be able to use digital platforms for information sharing, use data for multi-objective decision-making, and collaborate with multiple parties such as owners, designers, constructors, suppliers, supervisors, consultants and platform service providers.

From the perspective of policy environment, the 15th Five-Year Plan period is a critical stage for basically realizing socialist modernization. The planning proposals emphasize further advancing the construction of Digital China, improving the basic system of data elements, promoting the in-depth integration of the real economy and the digital economy, fully implementing the "Artificial Intelligence +" initiative, and coordinating the integrated development of education, science and technology, and talents. These orientations are highly consistent with the trends of digitalization, intellectualization, platformization and supply chain orientation in the engineering construction industry, and also provide a realistic basis for the reform of talent cultivation in engineering management majors [3-5].

Based on this, this paper focuses on answering four questions: what are the deficiencies in the cultivation of supply chain collaborative management competency for engineering management majors under the digital background; how to clarify cultivation content and competency boundaries with knowledge graphs and competency graphs; how to construct a D-KCJP five-element coupled competency cultivation model with theoretical logic; and how to promote the implementation of the model through curriculum systems, job tasks, implementation paths and guarantee mechanisms.

2. Current situation and problem analysis of supply chain collaborative management competency cultivation for engineering management majors under digital background

Compared with traditional engineering project management, engineering supply chain collaboration in the digital era presents characteristics such as diversified subjects, real-time data, linked decision-making and risk spillover. Material supply, construction schedule, cost payment, contract claim, quality control and platform data sharing interact with each other, and delays in a single link may spread to other links through the supply chain network. The current cultivation system mainly has the following problems [6, 7].

2.1. Cultivation objectives: insufficient transformation from knowledge mastery to job competence

The cultivation objectives of some majors still remain at the level of "mastering basic theories and methods of engineering management", and the expression of competency objectives such as supply chain collaboration, digital platform application, cross-organizational communication and complex problem decision-making are not specific enough, making it difficult for collaborative competency to become trainable, observable and evaluable learning outcomes.

2.2. Curriculum content: insufficient connection between engineering management knowledge and supply chain knowledge

Engineering management knowledge and supply chain knowledge such as procurement management, engineering logistics and material management are scattered in different courses, lacking unified knowledge graph and curriculum group design, making it difficult for students to holistically understand the coupling relationship among logistics, information flow, capital flow, responsibility flow and data flow.

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2.3. Practical teaching: insufficient training in real collaborative scenarios and complex tasks

Supply chain collaborative competency is highly contextual. Relying only on single course assignments, static cases or single job tasks, it is difficult for students to experience real engineering problems such as multi-party games, plan changes, supply interruptions and multi-objective conflicts.

2.4. Digital platform: insufficient integration of tool operation and management decision-making

BIM, project management software, data analysis tools or collaboration platforms have been introduced in many courses, but the teaching focus often stays on software operation, failing to be deeply integrated with supply plan adjustment, cost deviation diagnosis, schedule risk early warning and collaborative meeting decision-making [2, 8].

2.5. Evaluation mechanism: emphasizing knowledge outcomes while neglecting process evidence and job adaptability

Traditional evaluation mostly relies on examinations, reports and individual assignments, with less attention to team collaboration process, role performance, platform data contribution, scheme iteration records and enterprise mentor feedback, making it difficult to fully reflect comprehensive competency.

3. Construction of D-KCJP five-element coupled competency cultivation model

In response to the above problems, this paper develops the three-tier framework of "industry demand — competency structure — cultivation path" into a closed-loop system of "digital context traction — knowledge graph support — competency graph transformation — job task anchoring — curriculum pathway implementation", and names it the D-KCJP five-element coupled competency cultivation model. Among them, D stands for Digital Context, K for Knowledge Graph, C for Competency Graph, J for Job Task, and P for Curriculum Pathway [6, 7].

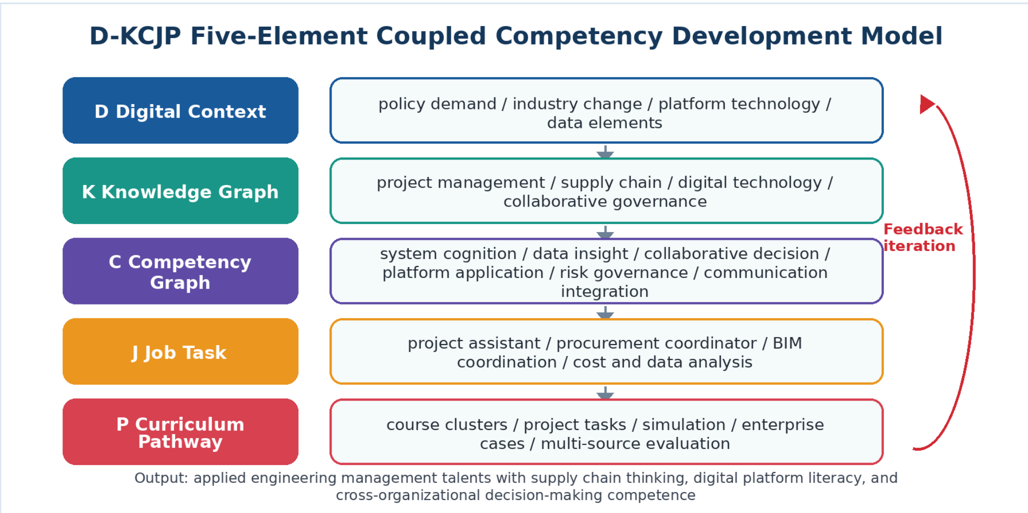

Figure 1. D-KCJP five-element coupled competency development model

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The core logic of the model is as follows: determining the cultivation direction based on policy environment, industrial transformation and technology application; integrating knowledge domains such as engineering project management, supply chain management, digital technology, collaborative governance and engineering economy with knowledge graphs; transforming into six types of competencies through competency graphs: systematic cognition, data insight, collaborative decision-making, platform application, risk governance and communication integration; deducing competency requirements from job tasks; and completing competency training through curriculum groups, project tasks, role division, digital platforms, enterprise cases and diversified evaluation.

4. Construction of knowledge graph and competency graph for knowledge system

4.1. Knowledge graph of engineering supply chain collaborative management

The function of knowledge graph is to make implicit knowledge structure explicit. The knowledge graph of engineering supply chain collaborative management takes "engineering supply chain collaborative management" as the core concept, connects outward to five knowledge domains: engineering project management, supply chain management, digital technology, collaborative governance and engineering economy, and is refined into knowledge nodes such as schedule, cost, procurement, logistics, BIM, data analysis, information sharing, risk sharing and contract claim [6, 7].

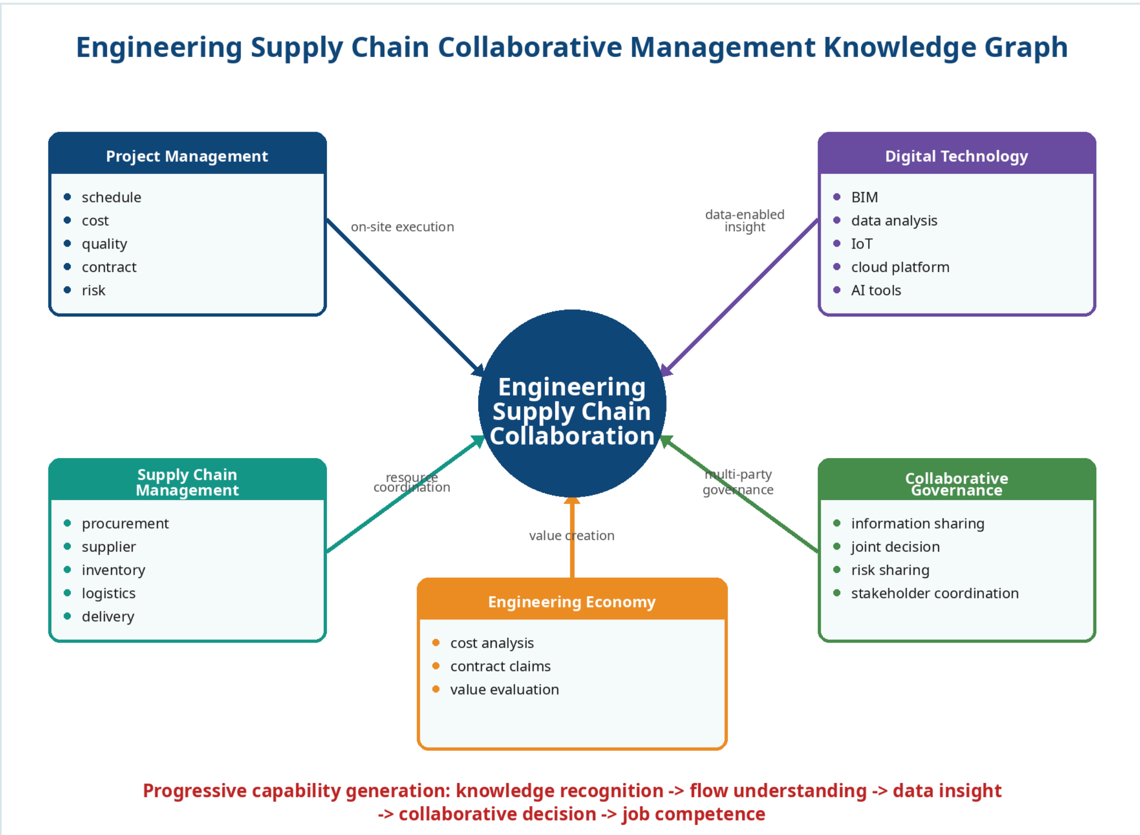

Figure 2. Knowledge graph of engineering supply chain collaborative management

In teaching, the knowledge graph mainly plays three functions: reorganizing curriculum content and transforming scattered knowledge points into project task chains; supporting learning path

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recommendation and pushing basic knowledge and training tasks according to students' weak links; and supporting the construction of teaching resources, binding cases, data packages, software operations, job tasks and evaluation scales to specific knowledge nodes.

4.2. Competency graph of supply chain collaborative management

The competency graph is the competency-based expression of the knowledge graph, emphasizing that students form observable behaviors in real tasks. This paper adopts a six-dimensional competency structure and introduces competency maturity levels, forming a competency description method of "dimension — behavior — evidence — level", so that competency cultivation shifts from abstract objectives to operable standards.

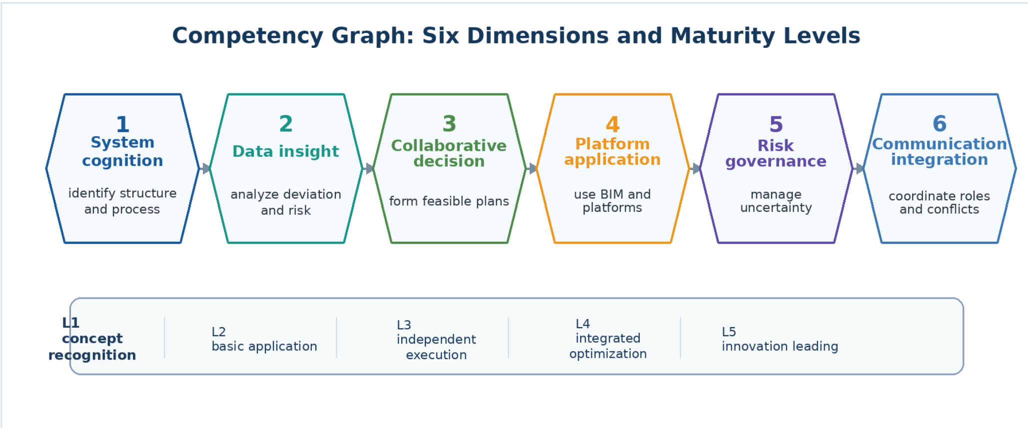

Figure 3. Competency graph of supply chain collaborative management: six dimensions and maturity levels

Table 1. Dimensions and performance indicators of supply chain collaborative management competency

Competency Dimension	Core Connotation	Typical Training Tasks	Evaluation Evidence
Systematic Cognition Competency	Identifying the structure, subject relationships and process coupling of engineering supply chains	Drawing project supply chain flow charts and subject relationship diagrams	Process integrity, accuracy of relationship identification
Data Insight Competency	Using project data to identify deviations, trends and risks	Schedule and cost data analysis, material demand forecasting	Data processing process, quality of analysis conclusions
Collaborative Decision-Making Competency	Formulating executable schemes under multi-objective constraints	Plan adjustment and cost trade-off under material delay	Scheme logic, decision-making basis, feasibility
Platform Application Competency	Using BIM, project management software or collaboration platforms to support management	BIM information extraction, task collaboration, kanban management	Platform operation records, effect of information sharing
Risk Governance Competency	Identifying risks such as supply interruption, price fluctuation and quality problems	Supplier alternative schemes, risk emergency plans	Risk list, completeness of emergency plans

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Table 1. (continued)

Communication Integration Competency	Carrying out cross-role communication, conflict coordination and team collaboration	Multi-subject collaborative meetings, role negotiations	Meeting minutes, team mutual evaluation, role performance

5. Design of supply chain collaborative management competency cultivation system under digital background

5.1. Design of curriculum system structure

Curriculum system design should avoid simply adding several digital courses or supply chain courses, but should carry out structural reconstruction around the competency graph. This paper proposes a five-module curriculum system of "basic courses — professional core courses — supply chain and collaboration courses — digital technology courses — comprehensive practical courses": basic courses focus on mathematics, management and economic foundations; professional core courses strengthen the whole life cycle management of engineering projects; supply chain and collaboration courses highlight procurement, suppliers, engineering logistics and collaborative governance; digital technology courses enhance the application of BIM, data analysis, intelligent construction platforms and artificial intelligence; comprehensive practical courses realize comprehensive application through enterprise project system, virtual simulation, cross-role sand table and graduation design [9, 10].

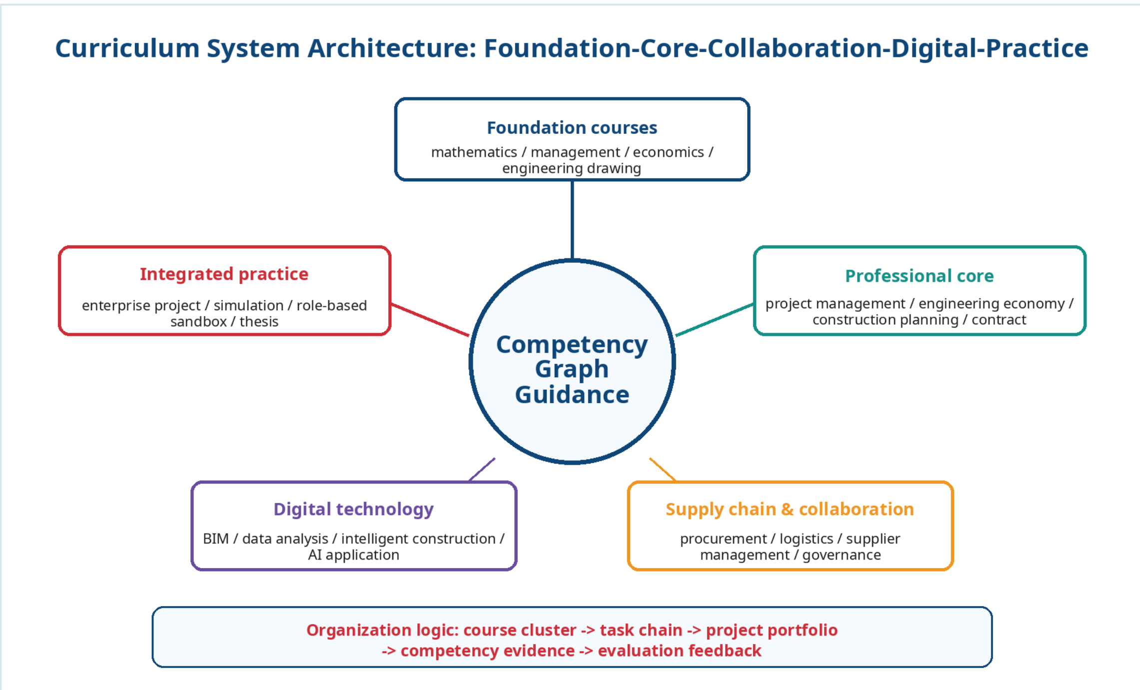

Figure 4. Curriculum system architecture: foundation-core-collaboration-digital-practice modules

5.2. Job-oriented mapping of competency and curriculum tasks

The positions for graduates of engineering management majors are not single project management positions, but a job group composed of project management, cost consulting, procurement and

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supply, BIM collaboration, project data analysis and whole-process consulting positions. Under the digital background, job competency requirements present the composite characteristics of "management knowledge + supply chain awareness + digital tools + data analysis + collaborative communication" [11].

Table 2. Mapping of job tasks, curriculum scenarios and competency requirements

Job Direction	Typical Job Tasks	Curriculum/Project Scenarios	Key Competencies
Assistant Project Manager	Schedule preparation, resource coordination, meeting organization	Comprehensive training on schedule adjustment of residential projects	Systematic cognition, communication integration, collaborative decision-making
Procurement/Supply Chain Coordinator	Supplier selection, procurement planning, delivery tracking	Scenario simulation of key material supply delay	Data insight, risk governance, collaborative decision-making
Assistant Cost Engineer	Cost estimation, change valuation, contract claim	Cases of material price fluctuation and cost control	Engineering economy, data insight, risk governance
BIM Collaboration Engineer	Model information extraction, collision coordination, platform sharing	BIM collaborative review and construction information linkage	Platform application, communication integration, systematic cognition
Assistant Project Data Analyst	Schedule and cost data kanban, risk early warning	Project data kanban and decision report	Data insight, platform application, collaborative decision-making
Assistant Whole-Process Consultant	Demand analysis, scheme comparison, organization and coordination, report preparation	Project feasibility and collaborative scheme design	Systematic cognition, collaborative decision-making, communication integration

5.3. Upgrading of project-driven, scenario-driven and collaboration-driven approaches

Project drive is the task carrier, answering "what project to learn"; scenario drive is the typical problem situation, answering "under what conditions to learn"; collaboration drive is the mechanism of role division and subject interaction, answering "how to form cross-organizational competency". The three are not parallel and isolated concepts, but a progressive relationship from project carrier to problem situation to collaborative behavior. Projects can be residential engineering, prefabricated buildings, municipal infrastructure or industrial park construction projects; scenarios revolve around material delay, design change, cost overrun, supplier breach of contract, schedule conflict and quality risk; collaboration is realized through role-playing, platform collaboration, collaborative meetings, scheme negotiation, team mutual evaluation and enterprise mentor feedback.

6. Implementation path and guarantee measures of the cultivation system

6.1. Implementation path

The cultivation system can be promoted in five stages: "demand diagnosis — graph modeling — scenario development — platform implementation — evaluation iteration": the first stage clarifies competency indicators through policy interpretation, industry research and job analysis; the second stage constructs knowledge graph, competency graph and curriculum mapping relationship; the third stage transforms graph content into project cases, task chains and role task sheets; the fourth stage carries out teaching implementation relying on BIM, project management software, data analysis

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tools and collaboration platforms; the fifth stage continuously optimizes through process data, work evaluation, student feedback and enterprise evaluation.

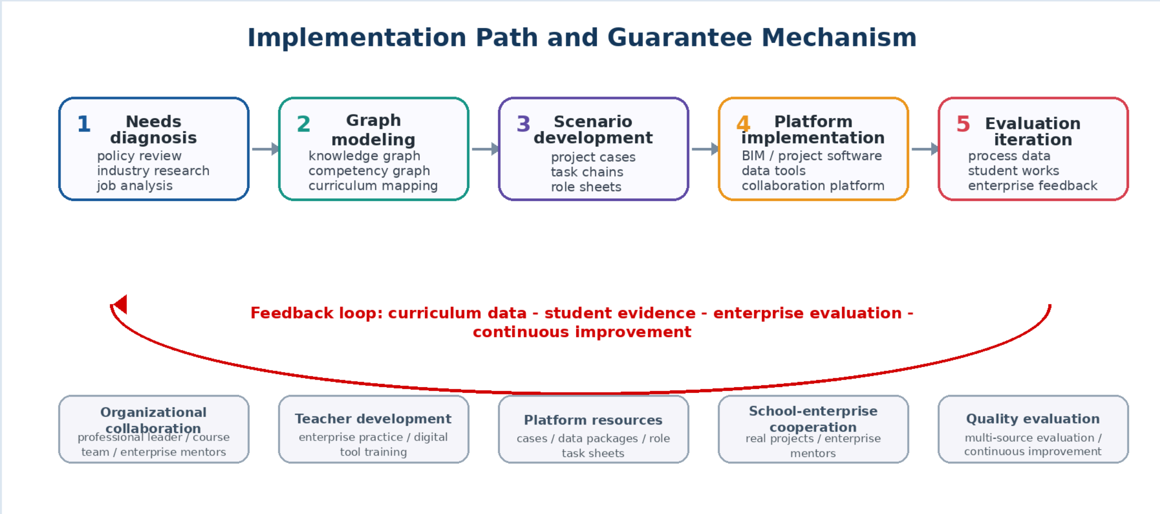

Figure 5. Implementation path and guarantee mechanism of the competency development system

6.2. Guarantee measures

Guarantee measures include five aspects: first, establishing a cross-subject organizational collaboration mechanism with the joint participation of major leaders, curriculum group teachers, enterprise mentors and digital platform technicians; second, building digital practice platforms and case resource libraries, forming software, data packages, role task sheets, collaborative meeting templates and evaluation scales; third, improving teachers' teaching competency in digitalization and supply chain collaboration, and promoting enterprise secondment, project research and cross-curriculum teaching and research; fourth, deepening school-enterprise cooperation and joint job cultivation, and transforming real enterprise tasks into hierarchical classroom tasks; fifth, improving the quality evaluation system and forming a diversified evaluation method combining individual evaluation, group evaluation, teacher evaluation, enterprise evaluation and platform evaluation [12].

7. Teaching case design: comprehensive training of supply chain collaborative management for residential engineering

A residential construction project is taken as a comprehensive training case. The project involves subjects such as the owner unit, design unit, general construction contractor, supervision unit, material supplier, equipment supplier and information platform service provider. In teaching, students are divided into groups with different roles to carry out collaborative management around material supply, construction schedule, cost control, quality risk and information sharing [13].

Table 3. Task chain of the comprehensive training project for residential engineering supply chain collaboration

Stage	Task Theme	Key Scenario	Student Output	Corresponding Competency
Task 1	Supply chain structure identification	Clarifying project subjects and process relationships	Subject relationship diagram, flow chart	Systematic cognition

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Table 3. (continued)

Task 2	Material demand planning	Calculating material demand according to construction schedule	Material demand sheet, procurement plan	Data insight
Task 3	Supply delay emergency response	7-day delay in delivery of key materials	Adjustment scheme, cost impact analysis	Collaborative decision-making, risk governance
Task 4	Platform collaborative meeting	Information sharing and negotiation among all roles	Meeting minutes, responsibility division sheet	Communication integration, platform application
Task 5	Comprehensive evaluation and reflection	Reviewing the effect of the scheme	Project report, personal reflection	Continuous improvement

Teaching evaluation can be divided into four links: "pre-test — process record — achievement evaluation — post-test feedback". The pre-test investigates students' mastery of engineering supply chain structure and digital tools; process records focus on platform login, data upload, role communication, meeting minutes and scheme optimization; achievement evaluation focuses on project reports, graphs, decision schemes and presentation defense; post-test feedback compares students' changes in systematic cognition, collaborative decision-making, data insight and team cooperation.

8. Conclusion

In the digital era, the cultivation of supply chain collaborative management competency for engineering management students should break through the limitations of single courses, single knowledge points and single-subject management, and carry out systematic cultivation for the whole process of engineering supply chain, multi-subject collaboration and digital platform application. Based on the policy orientation of Digital China construction, artificial intelligence-enabled industrial development and modern industrial system construction during the 15th Five-Year Plan period, this paper constructs a D-KCJP five-element coupled competency cultivation model, and proposes knowledge graph, competency graph, curriculum system structure, job task mapping, implementation path and guarantee measures.

The study holds that engineering management majors should be oriented by industry demand, sort out the curriculum content system with knowledge graphs, determine cultivation objectives with competency graphs, anchor practice scenarios with job tasks, promote competency training with digital platforms, and realize continuous improvement with diversified evaluation. Through the systematic reform of "graph traction, task integration, platform empowerment and evaluation closed loop", students' comprehensive competence for positions such as engineering supply chain collaboration, digital project governance and cross-organizational decision-making can be improved.

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