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PDCO Model-Based Design of Vocational Undergraduate Courses

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Abstract: *In response to the structural difficulties of vague goals, disciplinary content, passive implementation, and single evaluation in the design of vocational undergraduate courses, this study introduces the "Project Driven Capability Oriented" (PDCO) teaching mode, aiming to construct a course design path suitable for the training of high-level technical and skilled talents. The study first elucidated the connotation, characteristics, and appropriateness of the PDCO model with "project as the carrier and capability as the core"; Secondly, four basic principles have been established: "ability goals first, typical project tasks, moderate knowledge embedding, and process evaluation accompanying"; Furthermore, a five step closed-loop operation path covering "job capability analysis → course goal determination → project task design → knowledge point embedding → teaching activity implementation → evaluation feedback" was constructed. A quasi experimental study using the course "Intelligent Connected Vehicle Technology" as an example shows that compared to traditional teaching methods, the PDCO model can significantly improve students' academic performance ($p<0.01$, Cohen's $d=1.12$) and satisfaction with enterprise evaluations, effectively strengthening students' ability to solve complex engineering problems. This study provides theoretical references and practical paradigms for the construction of vocational undergraduate engineering courses.*

Keywords: *vocational undergraduate program; Project driven; Capability oriented; Course design; Intelligent Connected Vehicle Technology*

1. Introduction

Vocational undergraduate education, a vital pillar of modern vocational education, aims to cultivate high-level technical and skilled talents with solid theory and practical ability[1]. Curriculum design is crucial for linking educational goals to talent quality[2]; however, current practices suffer from "academicization" and a disconnect from practice. Key issues include vague objectives, fragmented content, passive teacher-centered delivery, and overreliance on summative exams[3].

To address these challenges, the "Project Driven & Competency Oriented" (PDCO) model emerges, emphasizing "learning by doing" and "learning for application" through real-world engineering projects[4]. This study explores PDCO's application by clarifying its principles, constructing a five-step closed-loop design path (competency analysis → task design → knowledge embedding → implementation → evaluation), and validating it via a case study on "Intelligent Connected Vehicle Technology" to offer practical reform paradigms.

2. Current Challenges and Model Relevance

Notwithstanding the rapid expansion of vocational undergraduate education, curriculum design at the micro-level remains constrained by traditional disciplinary paradigms. Structural contradictions persist across goal setting, content organization, instructional delivery, and assessment, resulting in a misalignment between talent supply and industry demands[3]. Specifically, four critical challenges emerge: (1) Goal ambiguity, characterized by vague behavioral descriptors (e.g., "master," "understand") that lack specificity for instructional guidance[1]; (2) Fragmented content, where an overreliance on subject-based logic undermines the integration of knowledge within work processes, leaving students unable to operationalize principles[2]; (3) Passive implementation, dominated by teacher-centered lectures that fail to engage learners in authentic exploration or higher-order thinking[3]; and (4) Terminal evaluation, marked by an overdependence on summative examinations, thereby neglecting the dynamic monitoring of skill acquisition and teamwork[5].

To address these deficiencies, the Project Driven Capability Oriented (PDCO) model is proposed. Centered on vocational competence development, this pedagogical framework utilizes typical engineering projects as carriers to embed learning within authentic work contexts. Its core tenets include reverse-designed competency goals, task-driven learning chains (cognition → specialization → synthesis), contextualized knowledge embedding for "learning by doing," and multifaceted process-oriented assessment[4]. By facilitating a paradigm shift from "knowledge input" to "competency output," the PDCO model provides a systematic solution to the aforementioned structural contradictions, as detailed in Table 1.

Table 1: Correspondence between Practical Problems in Vocational Undergraduate Course Design and the Suitability of PDCO Model

Practical Problem	Specific Manifestations	PDCO Solution Strategy	Theoretical Support
Fuzzy Goals	Use of abstract terms (e.g., "master," "understand"); Disconnection from job requirements.	Competency Goal First: Adopt behavioral expressions ("Ability + Action + Object + Condition") to ensure measurability.	OBE Concept (Outcome-Based Education); Reverse design of curriculum objectives.
Fragmented Content	Dominance of disciplinary systems; Lack of logical connection between theory and practice.	Project Task Restructuring: Use typical engineering projects as carriers to embed discrete knowledge into task processes.	Systematized Work Process Theory; Knowledge serves action.
Passive Implementation	Teacher-centered lectures; Low student participation ("operating machines on a blackboard").	Task-Driven Teaching: Design a complete action chain ("Introduction → Planning → Implementation → Presentation").	Constructivist Learning Theory; Emphasis on "Learning by Doing."
Single Evaluation	Over-reliance on final exams; Lack of corporate perspective and process monitoring.	Accompanying Process Evaluation: Establish a dual system of "Process + Result" with multi-party participation.	Developmental Evaluation Theory; Focus on diagnostic and improvement functions.

In summary, the PDCO model is not a partial repair of traditional teaching, but a systematic structural reshaping. It uses the project as a link to transform the competency requirements of vocational positions into implementable teaching activities, effectively bridging the gap between school education and workplace needs, and has important relevance for improving the quality of vocational undergraduate talent training.

3. Basic Principles of Course Design

Under the "Project Driven Capability Oriented" (PDCO) model, the design of vocational undergraduate courses must break through the constraints of traditional disciplinary systems and follow a set of systematic principles centered on vocational abilities. These principles support each other and together form the value foundation for the implementation of this model, ensuring that teaching activities comply with both educational laws and industry needs. Specifically, the following four basic principles should be followed.

3.1 Priority of Competency Objectives

The epistemological foundation of vocational undergraduate education resides in job positions rather than textbook taxonomies; consequently, the traditional "knowledge reserve paradigm" must yield to an "ability performance paradigm"[1]. Thus, curriculum design must initiate not with content planning, but with the deconstruction of typical job tasks to establish specific, observable, and measurable competency goals. Objective formulation necessitates eschewing vague psychological verbs (e.g., "mastery") in favor of Mager’s (1997) behavioral architecture—"Ability + Action + Object + Condition"—exemplified by transforming "mastering sensor principles" into "calibrating millimeter-wave radar within 30 minutes to output detection data with <5% error."[6] Grounded in Outcome-Based Education (OBE), this approach furnishes a clear trajectory for instructional activities and establishes an objective benchmark for subsequent evaluation[7].

3.2 Typicality of Project Tasks

Serving as the primary vectors for knowledge and skill acquisition, the quality of projects is paramount to pedagogical efficacy within the PDCO framework. This model prioritizes the selection of typical projects derived from authentic work environments over contrived exercises[2]. Typicality is defined along three dimensions: authenticity (originating from real production processes), comprehensiveness (covering multiple competencies to foster integrated application), and transferability (enabling the generalization of problem-solving logic to analogous contexts)[8]. Furthermore, acknowledging the cognitive trajectory from novice to expert[9], project design must adopt a progressive structure that facilitates a spiral ascent from discrete skill training to complex systems engineering practice.

3.3 Moderate Embedding of Knowledge

Regarding content architecture, the PDCO model necessitates a paradigm shift from the linear logic of disciplinary knowledge to the action logic of work processes. Adhering to the principle of "sufficiency in measurement and application priority," theoretical knowledge is contextually embedded into project task execution[4]. This entails selecting knowledge based on its necessity for specific tasks rather than systemic integrity, with presentation sequences aligned to the "task implementation process" rather than traditional textbook taxonomies. For instance, in the "CAN Bus Communication Analysis" project, the data frame structure is introduced solely upon the need to parse messages. Such situational embedding transcends rote theoretical indoctrination, enabling learners to grasp the teleology of knowledge and effectively resolving the dichotomy between theory and practice[9].

3.4 Continuous Process Evaluation

Transcending its traditional role in student classification, evaluation within the PDCO framework is reconceptualized as a catalyst for learning, necessitating an accompanying and diversified assessment system[10]. This entails: (1) Omnipresent evaluation, integrating feedback loops across project planning, execution, and presentation; (2) Pluralistic assessors, shifting from monolithic instructor judgment to a composite structure incorporating self-assessment, peer review, and enterprise mentorship; and (3) Criterion-referenced indicators, benchmarking operational standardization and problem-solving against predefined competency goals. A weighted allocation (Process: 40–50%; Outcome: 50–60%) is recommended to balance final deliverables with developmental trajectories[5]. In summary, these four principles constitute a rigorous logical whole (see Figure 1): the competency objectives define the "end point", typical projects provide the "carrier", knowledge embedding ensures the "support", and process evaluation guarantees the "achievement".

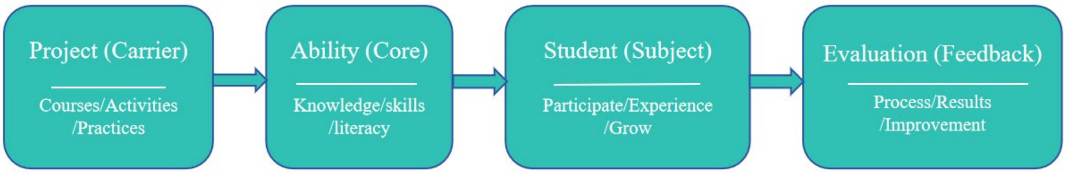

Figure 1: Core Logic Diagram of PDCO Mode

4. The operational path of course design

To ensure the effective implementation of the "Project Driven Capability Oriented" (PDCO) model, this study constructed an operational path consisting of five interconnected and logically progressive steps. This path forms a complete closed loop from job requirement analysis to ability achievement verification, aiming to transform abstract "ability goals" into concrete "teaching actions"[2]. Refer to Figure 2.

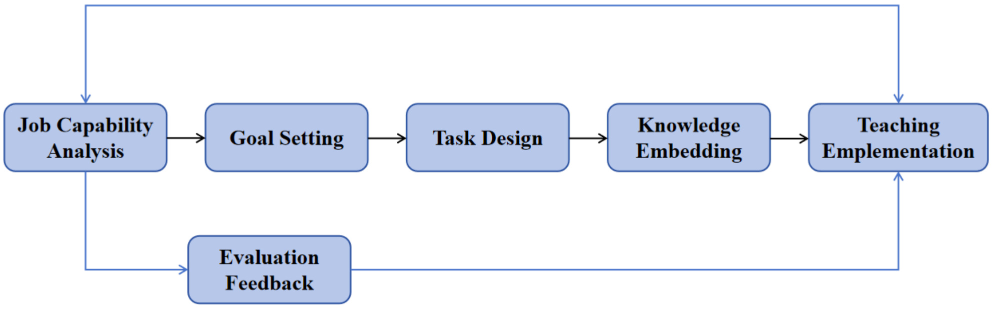

Figure 2: Five step closed-loop operation path diagram for PDCO course design

4.1 Step 1: Job Capability Analysis → Course Capability Goal Determination

Serving as the logical genesis of curriculum design, this phase centers on the precise transmutation of "industry demands" into "course objectives." Designers must identify typical job tasks through enterprise research, expert interviews, and job analyses[8]. Subsequently, grounded in Bloom's Taxonomy[11], broad vocational competencies are distilled into specific, measurable curricular goals. Adhering to Mager's (1997) behavioral paradigm—"Ability + Action + Object + Condition"—this formulation eschews unobservable constructs (e.g., "mastery") to ensure the objectives' directive validity for both instructional delivery and assessment[6].

4.2 Step 2: Decomposition of Capability Objectives → Project Task Design

This phase seeks to identify an appropriate vector for competency instantiation. Designers must deconstruct comprehensive capability goals into discrete yet progressively interrelated project tasks. High-quality tasks necessitate typicality, feasibility, and comprehensiveness[4]. Grounded in Vygotsky's (1978) Zone of Proximal Development, the design must establish an advanced sequencing—from discrete skills to comprehensive application—to ensure a spiral ascent in student competence throughout project execution[12].

4.3 Step 3: Project Task Deployment → Knowledge Point Embedding

This phase supplants the linear logic of disciplinary knowledge with the action logic of work processes. Adhering to the principle of "sufficiency in measurement," requisite theoretical knowledge is contextually embedded into nodes of project execution[1]. The sequencing of knowledge points aligns strictly with the task trajectory (e.g., selection → installation → debugging → troubleshooting), eschewing traditional textbook taxonomies. This strategy of "contextualized embedding" effectively resolves the dichotomy between theory and practice, fostering the deep integration of declarative and procedural knowledge[13].

4.4 Step 4: Teaching Activity Design → Task Driven Process

Focusing on classroom enactment, this phase advocates for the "Five-Step Instructional Method" to realize a student-centered paradigm[14]. The protocol comprises: (1) Task Introduction (≈5 min), establishing authentic contexts; (2) Knowledge Preparation (≈15 min), featuring targeted instruction on core difficulties; (3) Planning Formulation (≈15 min), involving collaborative scheme development; (4) Task Implementation (≈40 min), encompassing hands-on operation with tutor guidance; and (5) Presentation & Evaluation (≈15 min), facilitating peer assessment and reflective summarization. This orchestrated process ensures students complete a comprehensive work cycle—from order reception to delivery—within the instructional timeframe.

4.5 Step 5: Evaluation Plan Design → Capability Achievement Test

This step aims to establish a "companion style" evaluation system that highly matches the target. Evaluation design should reflect the characteristics of balancing process and outcome, and involving multiple stakeholders[10]. It is recommended to adopt a "four-dimensional evaluation index system", as shown in Table 2 for specific examples.

Table 2: Example of Project Task Evaluation Indicator System (Taking Sensor Installation and Adjustment Project as an Example)

Evaluation dimension	Specific indicators	Criteria	Weight
Design Scheme	Rationality and feasibility of the plan	Clear logical steps, correct tool selection, and thorough risk assessment	20%
Operation implementation	Operational standardization and safety	Compliant with industry safety regulations, proficient in tool use, and error free wiring	30%
Result Quality	Accuracy and completeness of data	Sensor calibration error ≤ 5%, point cloud data complete without loss	30%
Professional Ethics	Team collaboration and communication expression	Clear division of labor, active participation in discussions, and clear reporting structure	20%

The weight of process evaluation and outcome evaluation are recommended to be set at 4:6 or 5:5 to ensure that both the "process of doing" and the "effect of doing" are emphasized[5]. Through the mechanism of "evaluation feedback improvement", achieve mutual growth between teaching and learning.

5. Case Study: Intelligent Connected Vehicle Technology Course

To validate the proposed five-step operational path, a quasi-experiment was conducted with two parallel classes (N=50 each) in New Energy Vehicle Engineering, randomly assigned to either an experimental group (PDCO model) or a control group (traditional mode). Enterprise evaluation, administered by five technical supervisors from three partner firms, utilized a 5-point Likert scale assessing "job adaptability," "problem-solving ability," and "team collaboration." Characterized by rapid technological iteration, high interdisciplinarity, and strong practicality, this course serves as an ideal specimen for testing the PDCO framework[15].

5.1 Curriculum Capability Goal Setting

Grounded in Step 1 (Job Competency Analysis), a DACUM (Developing A Curriculum) seminar involving local industry technical backbones was convened to delineate the core responsibilities of the "Intelligent Connected Vehicle Tester" role. This collaboration yielded four measurable course competency objectives, structured by a progressive cognitive-to-operative logic:

Holistic Cognition: Identify and describe the technical architecture and critical components governing the "Perception-Decision-Execution" continuum of intelligent connected vehicles;

Specialized Skills: Independently execute the installation and calibration of LiDAR and millimeter-wave radar, accurately interpreting point cloud and obstacle data (error <5%);

Systems Analysis: Utilize tools (e.g., CANoe) to capture and parse onboard CAN bus messages, diagnosing communication link status;

Comprehensive Application: Construct a Lane Keeping Assistance (LKA) model via MATLAB/Simulink and execute fundamental simulation testing.

5.2 Mapping project tasks and knowledge points

To elucidate the progression from discrete skills to systemic integration, this study establishes a technical chain—"Perception → Communication → Decision-Control." As depicted in Figure 3, Project One targets the foundational environmental perception layer (sensor installation/adjustment); Project Two addresses the network communication layer (CAN bus analysis) to establish data transmission links; and Project Three advances to the decision-control layer (LKA simulation) for comprehensive system integration. Grounded in the cognitive trajectory of "single → specialized → comprehensive" skills[9], this tiered design ensures a spiral escalation in student competence, with the specific task-knowledge mapping detailed in Table 3.

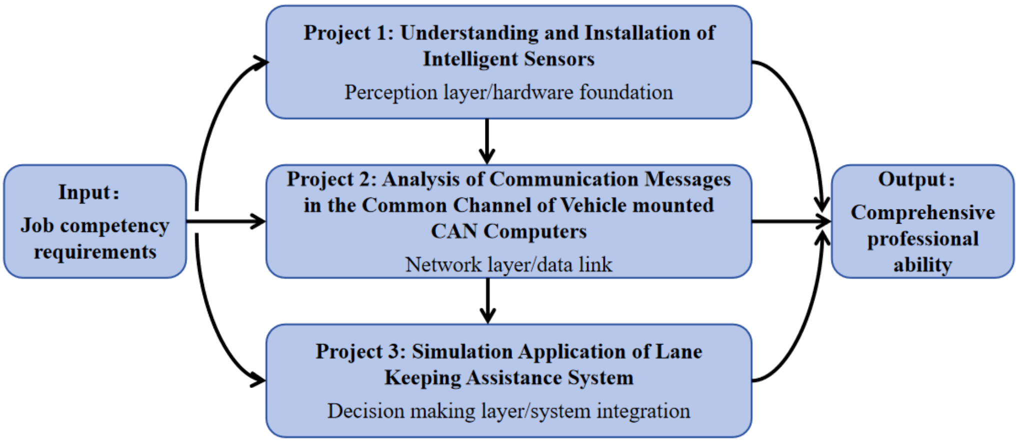

Figure 3: Progress diagram of tasks for the "Intelligent Connected Vehicle Technology" project

According to "Step 2" and "Step 3", break down the above ability goals into three progressive project tasks, and embed knowledge points as needed. The mapping relationship is shown in Table 3 below.

Table 3: Mapping Table of Tasks and Knowledge Points for the "Intelligent Connected Vehicle Technology" Project

Project Task	**Competency Targets**	**Embedded Knowledge Points**	**Hours**
Project 1: Understanding and Installation of Intelligent Sensors	Goal 2 (Supporting Goal 1)	Working principle of sensors (ToF/Doppler effect); Installation location and calibration process; Common fault diagnosis and troubleshooting	8
Project 2: Analysis of Vehicle CAN Bus Communication Messages	Goal 3	Fundamentals of CAN bus protocol; Data frame structure (arbitration field, data field); Instructions for using CANoe tools; Typical signal analysis	8
Project 3: Simulation Application of Lane Keeping Assistance System	Goal 4 (Integrated Application)	Principles of Visual Perception Algorithms; PID control logic; Simulink Modeling Fundamentals; V-Model development process	12

The three projects form a complete technical chain of "perception → communication → decision control", ensuring that students' abilities are gradually improved from a single skill to a system level comprehensive application.

5.3 Teaching Implementation and Empirical Effect Analysis

Adhering to Steps Four and Five, the curriculum employed the "Five-Step Instructional Method" alongside a dual "Process + Result" evaluation system (see Table 2). A one-semester quasi-experiment was conducted with two parallel classes (N=50 each), comparing the PDCO model against a traditional "lecture + confirmatory experiment" control.

Independent samples t-tests on final grades revealed statistically significant improvements in the experimental group (M=86.7 vs. 75.4; t=5.32, $p<0.01$, Cohen’s d=1.12), with a 22.5% advantage specifically in "comprehensive fault diagnosis." Skill acquisition was superior, evidenced by a 92% first-pass rate in "sensor installation and adjustment" versus 71% in the control group. Furthermore, enterprise evaluations during internships rated the experimental group significantly higher on "job adaptability" and "problem-solving ability" (4.7/5.0 vs. M=4.1)[5]. These findings substantiate that the PDCO model effectively enhances learning initiative and complex engineering problem-solving capabilities, confirming its applicability and superiority in advanced vocational undergraduate education.

6. Discussion and Suggestions

Although the "Project Driven Capability Oriented" (PDCO) model has achieved significant results in the course of "Intelligent Connected Vehicle Technology", it still faces dual constraints in terms of faculty capacity and resource conditions when promoted to other professional courses in vocational undergraduate programs. This chapter will delve into implementation bottlenecks and propose targeted strategic recommendations.

6.1 Reconstruction of the teaching staff's abilities: from "dual teachers" to "dual abilities"

The implementation of the PDCO model imposes novel demands on educators' composite competencies, rendering the traditional "dual-qualified" teacher paradigm—defined by academic and professional certifications—insufficient for project-based pedagogy[16]. Consequently, instructors must transition from mere "knowledge transmitters" to facilitators of learning and project designers. This necessitates the cultivation of four specific capacities: (1) Industry cognitive ability, to capture technological frontiers and deconstruct typical work tasks[2]; (2) Project conversion ability, to transform complex engineering cases into pedagogically appropriate classroom projects[4]; (3) Instructional regulation ability, to dynamically balance student autonomy ("release") with instructional guidance ("collection") amidst evolving classroom contexts[14]; and (4) Process evaluation ability, shifting from singular examination to multidimensional diagnosis and feedback.

To address these requirements, a "school-enterprise bidirectional mobility" mechanism is recommended. This involves implementing "Mobile Stations for Teacher Enterprise Practice," mandating a minimum of six months of full-time industrial engagement per five-year cycle[17], and establishing "Distinguished Industry Mentor" positions. Such measures facilitate the formation of a "dual-mentor" team dedicated to co-developing project repositories and curriculum standards.

6.2 Adaptive upgrade of teaching resources and environment: combination of virtual and real

The PDCO model necessitates authentic, "real weapon" practice, imposing stringent demands on the sophistication of training apparatus and the breadth of case repositories. However, the prohibitive unit costs and rapid technological obsolescence of Intelligent Connected Vehicles (ICVs) predispose institutions to a "financially unsustainable and technically outdated" predicament under a hardware-exclusive investment strategy[15].

To mitigate these constraints, a "virtual-real integration" strategy is advocated. This hybrid approach leverages "software simulation + hardware verification": high-fidelity simulations via MATLAB/Simulink and PreScan are employed for protocol analysis and algorithm validation to curtail hardware dependency, while limited physical devices are reserved for sensor calibration and bus communication tasks[18]. This paradigm not only reduces procurement expenditure but also mitigates safety hazards associated with high-voltage systems. Complementarily, establishing a dynamically updated, shared case repository—co-developed by faculty and industry to transform genuine faults into pedagogical projects—facilitates cross-institutional resource sharing and circumvents redundant construction.

6.3 The applicable boundary and promotion path of the pattern

While the PDCO model offers significant pedagogical advantages, it is not universally applicable. Its efficacy is primarily confined to practice-oriented and technology-intensive disciplines, such as engineering and information technology. For public foundational courses (e.g., mathematics and English), cautious implementation or auxiliary utilization is advised to prevent undermining the systematic integrity of subject knowledge[1].

Regarding dissemination, a phased implementation pathway—"Pilot → Iterative Optimization → Comprehensive Promotion"—is recommended. Institutions should initiate reforms in 1–2 core courses to accumulate procedural artifacts (e.g., project manuals, assessment rubrics) before scaling the paradigm across professional clusters. Concurrently, reforming the academic evaluation system to incorporate "teaching reform achievements" and "industry-education integration cases" into faculty promotion and performance metrics is essential for incentivizing curricular innovation[19].

7. Conclusion

This study addresses structural deficiencies in vocational undergraduate course design by constructing a "Project Driven Capability Oriented" (PDCO) teaching model and a corresponding five-step operational path, with effectiveness validated via the "Intelligent Connected Vehicle Technology" course. The principal innovations comprise: (1) Precise positioning, addressing the micro-level research gap in curriculum design for high-level technical and skilled talent cultivation[1]; (2) Path systematization, proposing a closed-loop framework—from competency analysis to evaluation feedback—that provides a replicable blueprint for instructors[2]; and (3) Empirical validation, utilizing quasi-experimental data ($p<0.01$, Cohen's $d=1.12$) to confirm the model's efficacy in enhancing students' complex engineering problem-solving abilities[15].

Nevertheless, limitations persist regarding sample singularity, insufficient long-term tracking, and the high implementation costs under resource constraints[16]. Future research will focus on the cross-disciplinary adaptation of the PDCO model (e.g., IT and modern services) and explore the integration of Generative AI (Gen AI) to optimize project design and personalized assessment, thereby refining the curriculum ecology of vocational undergraduate programs.

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