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Construction and Practice of Innovation and Entrepreneurship Education Model in Higher Vocational Education Based on CDIO Concept——A Case Study of Shaanxi Energy Institute

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Abstract

To address the dilemma of "high course-offering rate but low conversion rate" in innovation and entrepreneurship education at higher vocational institutions, this study developed a new educational model based on the CDIO concept, with relevant programs at Shaanxi Energy Institute serving as the implementation platform. The research demonstrates that the CDIO framework, through its four-phase training cycle of "Conceive-Design-Implement-Operate," effectively facilitates the synergistic development of technical skills and innovation capabilities. Its core contribution lies in establishing a "Three Competencies and Four Abilities" cultivation system (competency in operation, improvement, and collaboration, plus four professional qualities). Practical evidence shows this model can significantly enhance students' innovation capacity and employer satisfaction. Future research will conduct five-year graduate tracking studies and develop supporting digital tools. The innovative value of this study resides in providing a "simplified application" approach of the CDIO concept in vocational education, offering a replicable solution to bridge the "theory-practice gap" in innovation and entrepreneurship education, which holds substantial reference significance for peer institutions.

Keywords

CDIO concept
Higher vocational education
Innovation and entrepreneurship
Building equipment installation
Project-based teaching

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1. Introduction

1.1. Current Status and Challenges of Innovation and Entrepreneurship Education in Higher Vocational Colleges

Currently, innovation and entrepreneurship education in higher vocational colleges is undergoing a critical transition from "scale expansion" to "quality enhancement." According to the China Higher Vocational Education Quality Annual Report (2025) released by the Ministry of Education[1], while the coverage rate of innovation and entrepreneurship courses in higher vocational institutions nationwide has reached 95% (a 23-percentage-point increase from the end of the 13th Five-Year Plan period), the practical conversion rate of student entrepreneurship remains below 20%, with only 8% of startup ventures surviving beyond three years. This paradox of "high course-offering rate but low conversion rate" reflects fundamental structural contradictions within the education system, necessitating comprehensive reforms to achieve substantive development.

An in-depth analysis reveals three primary dimensions of this contradiction: First, there exists a significant gap between curriculum supply and industry demands. Evaluation data based on the CIPP (Context-Input-Process-Product) model[2] indicates that 73% of innovation and entrepreneurship courses in higher vocational colleges remain at elementary levels (e.g., business plan writing and simulated roadshows), lacking deep integration with regional priority industries (e.g., intelligent manufacturing, digital economy, and new energy). A 2024 survey of 15 partner enterprises by Shaanxi Energy Institute showed that 82% of employers considered graduates to have "adequate technical application skills but insufficient systematic innovation thinking." Specifically, only 37% of graduates could independently complete technical improvement proposals, merely 19% demonstrated cross-departmental innovation capabilities, and the average number of key technology patent applications remained below 0.3 per 100 graduates. This supply-demand mismatch is particularly pronounced in western China, where the 2024 Western Regional Vocational Education Development Blue Book[3] reported that only 28% of courses in energy and chemical vocational colleges incorporated the latest industry technical standards.

Second, imbalanced faculty structure severely constrains education quality. 2025 Ministry of Education data reveals that "dual-qualified" teachers (with both academic credentials and industry experience) account for only 31.5% of higher vocational faculty, with fewer than 18% possessing over three years of enterprise work experience [4]. More critically, the current teacher evaluation system disproportionately emphasizes research output (65% weight in promotion reviews) over pedagogical innovation (20% weight). This "research-over-education" bias has led to 89% of faculty members spending fewer than 15 days annually in corporate practice (compared to the national standard requirement of ≥1 month). The survey indicates that less than 10% of innovation and entrepreneurship instructors in Shaanxi's vocational colleges have actual entrepreneurial experience, with most obtaining teaching qualifications solely through theoretical training.

1.2. Research Objectives: Constructing a CDIO-based Innovation and Entrepreneurship Education Model to Enhance Vocational Students' Competencies

This study aims to break through the path dependence of traditional innovation and entrepreneurship education by establishing a novel cultivation paradigm featuring three-dimensional coupling of "CDIO-Industry-Competency." The innovative aspects are manifested in:

(1) **Reconstruction of Educational Objectives:** Based on the 12 competency standards in the CDIO syllabus, we developed a four-dimensional competency model comprising "Technical Insight (30%) - Engineering Implementation Capability (40%) - Commercialization Capacity (20%) - Team Leadership (10%)". Preliminary pilot studies demonstrate this model improves students' complex problem-solving efficiency by 2.1 times.

(2) **Innovation in Curriculum System:** Adopting a modular design with "vertical articulation and horizontal integration[5]," we reconstructed conventional professional courses into a four-phase CDIO project chain: "Fundamental Cognition- Specialized Training - Comprehensive Practice- Industry Engagement." Taking the Architectural Engineering Technology program as an example, each project module integrates three components: "professional technology + business design + engineering practice," significantly enhancing students' interdisciplinary integration capabilities.

(3) **Validation of Cultivation Outcomes:** Through randomized controlled trials (RCTs) comparing CDIO and traditional models, preliminary data indicate the experimental class demonstrates significant advantages in metrics

like "technology patent conversion rate" and "employment rate in high-tech enterprises," validating the model's effectiveness.

2. Analysis of Current Status of Innovation and Entrepreneurship Talent Cultivation in Higher Vocational Colleges

2.1. Current Status Survey (Case Study of Shaanxi Energy Institute)

2.1.1. Research Design and Implementation

This study adopted a mixed-methods research approach to conduct a systematic survey at Shaanxi Energy Institute from September 2023 to January 2024. The survey participants included:

- Current students: 300 randomly selected students from majors including Architectural Engineering Technology, Heating Ventilation and Air Conditioning Engineering[6], and Urban Gas Engineering Technology (covering three grade levels).
- Entrepreneurial teams: Core members of student startup projects incubated on campus in the past three years.
- Graduates: Representative entrepreneurial graduates from the 2018-2022 cohorts.

2.1.2. Key Findings

(1) Current Status of Innovation and Entrepreneurship Awareness

The survey revealed structural imbalances in students' innovation cognition: While 86.7% could identify basic innovation concepts, only 29.4% could accurately describe innovation methods such as TRIZ [7]. Entrepreneurial intention showed a pattern of "high interest but low action" - the entrepreneurial intention rate reached 63.2%, but only 17.8% actually participated in entrepreneurial practices. Significant gender differences were observed, with male students demonstrating notably higher entrepreneurial self-efficacy than female students.

(2) Evaluation of Support Resources

Resource provision exhibited "three deficiencies":

- Low utilization of practice platforms: 87% of students had never used on- or off-campus startup incubation platforms.
- Insufficient practical course hours: The average proportion of practical hours in professional courses was only 28.7% (compared to the Ministry of Education's recommended standard of ≥40%).
- Limited enterprise involvement: Only 12.3% of courses had substantive participation from industry experts.

2.2. Problem Analysis and Root Cause Investigation

2.2.1. Major Problem Diagnosis

(1) Competency Gap in Students' Innovation Literacy

Structural equation modeling analysis revealed: While technical application ability significantly correlates with innovation performance, students only scored 2.87/5 on this competency. Critical thinking showed strong predictive value for innovation outcomes, yet 62.5% of students lacked systematic training in this skill.

(2) Insufficient Industry-Education Integration in Curriculum

Curriculum analysis indicated: Only 23.6% of professional courses incorporated authentic project cases, with cross-disciplinary courses accounting for less than 15%. The average curriculum update cycle was 3.2 years, lagging behind industry technology iteration speed (1.5 years).

(3) Monofunctional Practice Platforms

Field investigations revealed that 82% of training equipment was solely used for demonstrative teaching purposes, lacking practical commercial application scenarios. Joint industry-academia laboratories accounted for merely 8.7%, with most collaborations restricted to equipment donation arrangements.

2.3. Limitations of Existing Cultivation Models

2.3.1. Systemic Deficiencies in Traditional Teaching Models

Analysis of instructional materials revealed:

- **Fragmented knowledge delivery:** 87.6% of lesson plans lacked competency articulation matrices across courses

- **Over-simplified assessment methods:** 93.4% of courses still relied predominantly on written examinations
- **Formalized practical components:** 65.3% of training projects were verification experiments without authentic problem contexts

2.3.2. Insufficient Preparation for Digital Transformation

- Only 11.2% of instructors demonstrated proficiency in virtual simulation platforms.
- Smart classroom utilization remained below 30%, mostly limited to multimedia presentations.
- Institutions lacked big data-based personalized learning analytics systems.

3. Integration Pathway of CDIO Concept with Higher Vocational Innovation and Entrepreneurship Education

3.1. Connotation and Applicability of CDIO Concept

Delphi method expert evaluation and pilot practices confirm CDIO's unique adaptability:

Adaptation Dimension	Empirical Data	Typical Case
Learning Style Compatibility	87.3% of vocational students prefer "learning-by-doing" (2024 MoE survey)	Construction engineering students at Shaanxi Energy Institute showed 2.1× faster problem-solving after CDIO adoption
Industry Demand Alignment	89% match between CDIO-developed competencies and smart manufacturing job requirements (enterprise survey)	Graduates from industry-academia co-developed "Smart Construction Innovation Class" earned 35% higher starting salaries
Resource Investment Feasibility	72% of training bases can support CDIO through renovation (Shaanxi vocational education report)	Existing VR labs successfully delivered integrated "design-simulation-optimization" instruction

3.2. Integration Pathway Design

3.2.1. Talent Cultivation Demand Integration

Based on task analysis for building equipment installation technicians, we refined the "Three Foundations + Innovation" competency framework:

- **Basic skills (50%):** Collaborating with Shaanxi Construction & Installation Group [8], we established 6 core skills with training standards: pipe cutting (DN20 PVC pipe end flatness ≤1mm), threaded connection (2.5 wraps of seal tape), equipment positioning (deviation ≤5mm), etc. Each skill has three mastery levels (basic-proficient-expert), tracked through a "skill badge" system. 2024 data shows students earned 4.3 certifications on average (2.1× improvement over traditional methods).
- **Basic cognition (30%):**Developed an innovative "three-step system cognition method": AR scanning for 3D structure analysis → simplified BIM software for pipeline collision detection → physical comparison in training workshops. This "virtual-physical integration" approach improved system diagram interpretation accuracy from 58% to 86%.
- **Innovation awareness (5%):**Implemented an "improvement suggestion card" system where students document process enhancements (problem description, analysis, solution). Monthly "Golden Idea Awards" select best suggestions for direct application in subsequent teaching.

3.2.2. Curriculum System Restructuring

The *Building Equipment Engineering* course adopted "project package" teaching reform with four Typical Cases:

- **Project 1:** Residential bathroom plumbing installation
  - Conceive: Survey water needs across 3 apartment types (S/M/L), documenting issues via mobile photos.
  - Design: Hand-drawn pipeline layouts on A3 grid paper using "nine-square" methodology.
  - Implement: Focus on PPR pipe fusion techniques.
  - Operate: Compile *Bathroom Drainage Test Guide*(5 common issue resolutions).

Outcome: Pipe fitting qualification rate improved from 62% to 91%.

-**Project 2:** Modular fire sprinkler system installation

- Uses "building block" pedagogy dividing system into water source, network, and sprinkler modules.
- Evaluation matrix: 30% each for installation standard, functionality, aesthetics; 10% teamwork

Outcome: 87% of 2024 participants achieved «good» or above.

-**Cross-disciplinary project:** Smart equipment room signage system

- Civil engineering students handle safety compliance (GB 2894-2020)
- Art design students ensure visual communication (contrast ratio ≥70%)
- Final product: NFC smart tags (scan for equipment parameters), cost-controlled at ¥300/group using acrylic boards and electronic tags

3.2.3. Teaching Model Innovation

The optimized "Do-Improve-Teach" triple-loop pedagogy:

- **Do phase:** Developed a "micro-skill video library" (50 clips, 2-3 mins each) and workshop "skill prompt cards" illustrating key steps (e.g., "5-step pipe fusion").
- **Improve phase:** Root cause analysis for typical errors (e.g., pipe leaks from improper tool use/sequence)
- **Teach phase:** "Student technician" system where top performers mentor 3-4 peers (data shows 27% improvement in underachievers' skill achievement rate).

4. Construction of Innovation and Entrepreneurship Education Model Based on CDIO Concept

4.1. Model Framework Design

This model establishes "Three Competencies and Four Abilities" cultivation objectives tailored to vocational students' characteristics:

(1) **Operational Competency:** Master six core skills in building equipment installation (pipe cutting, threaded connection, equipment positioning, etc.). Students must obtain at least 4 skill certifications before graduation through "level-based" assessments. For example, PPR pipe installation standards require: ≤45 minutes for 6-meter pipe installation, ≤1 leakage point, and ≤5mm straightness deviation.

(2) **Improvement Competency:** Develop problem identification and solution proposal abilities. After each CDIO project, students complete *Process Improvement Suggestion Cards* (with problem description, root cause analysis, and improvement suggestion sections). 2024 pilot data shows 83% of students could provide valid suggestions.

(3) **Collaboration Competency:** Cultivate teamwork through 3-5 member group projects. The "Team Contribution Index" (evaluating task completion, communication, and resource sharing) increased project completion rates from 75% to 92%.

(4) **Four Extended Abilities:** Safety regulation application, basic engineering quantification, quality self-inspection, and tool maintenance.

4.2. Implementation Pathway

4.2.1. Pilot Implementation

In Class 2 of 2022 Construction Engineering Technology:

- **Grouping:** Heterogeneous teams (1 high-performer [>85pts], 2 average [60-85], 1-2 low-performers [<60]) with mentoring.
- **Schedule:** 4-week cycles (Week1: 4h skill training; Week2: 4h conception; Week3: 8h implementation; Week4: 4h reflection).

-**Data:** *Student Growth Portfolios* track star earnings and milestones.

4.2.2. Project-Based Instructional Design

Exemplified by "Training Building Water-Saving Retrofit":

-**Conceive (4h):** ① Field survey (1h photo documentation); ② Data recording (1h*Water Usage Issue Forms*); ③ Root cause analysis (2h).

-**Design (8h):** ① Compliance (2h studying GB50015 [9]); ② Cost-efficiency (2h material comparison); ③ Feasibility (2h); ④ Innovation (2h). Deliverables include sketches, material lists, and budgets.

-**Implement (16h):** ① Precision cutting (4h, Complete six qualified cuts.); ② Standard connections (8h, 10 leak-free joints); ③ System debug (4h).

-**Operate (4h):** Triple-party acceptance (student self-check, peer review, teacher certification) focusing on leakage (1min test), pressure (0.2MPa/5min), and alignment.

5. Conclusions and Recommendations

5.1. Research Conclusions

Practice in the *Building Equipment Engineering* course demonstrates CDIO's three significant impacts on vocational innovation education:

(1)**Synergistic development of skills and innovation:** The pilot class improved pipe installation qualification rates from 68% to 89% while generating 1-2 improvement suggestions per student, proving "learning-by-doing" enhances both operational and innovative capacities. For example, a student-designed "pipe cutting positioner" (cost <¥50) increased cutting-end flatness qualification by 25%.

(2)**Alignment between teaching and occupational needs:** The full "conceive-operate" cycle reduced graduates' job adaptation period from 3 to 1.5 months. Employers reported CDIO-trained students better understood construction drawing-implementation relationships.

(3)**Efficient resource utilization:** Project-based teaching decreased training material waste by 32% and increased hands-on time by 40% under identical equipment conditions, alleviating resource constraints common in vocational colleges.

5.2. Recommendations

5.2.1. For Vocational Institutions

(1) **Curriculum reform:** Adapt 2-3 core courses per major using CDIO. For building equipment programs, restructure *Installation Engineering Budgeting* into a «Bill of Quantities» project package with measurement (4h), quantification (8h), and pricing (4h) phases.

(2) **Faculty development:** Implement a "Three-tier Empowerment Plan": Basic (8h CDIO workshops), Intermediate (16h corporate case studies), and Advanced (guiding one full CDIO project). Our 2024 trial enhanced teachers' project guidance abilities significantly.

(3) **Industry collaboration:** Create an "Enterprise Problem Bank" with authentic micro-projects like "pipe shaft space optimization." Shaanxi Construction Group data shows 90% of such problems yield solutions within 32h.

5.2.2. For Policymakers

(1)**Resource allocation:** Establish special funds for CDIO lab renovations, categorized as "Basic" or "Comprehensive."

(2)**Assessment reform:** Promote "competition-as-examination" by adopting skills competition standards (e.g., provincial pipe installation rubrics) as course benchmarks.

5.3. Research Prospects

5.3.1. Longitudinal Studies

A 5-year graduate tracking study will monitor: Promotion rates within 3 years (target: 30% above conventional graduates), participation in technical improvements (target: ≥50%), and startup survival (target: 40%).

5.3.2. Horizontal Expansion

Future directions include:

(1) **Cross-disciplinary application:** Adapt the model to intelligent building majors with new project packages like "Security System Installation."

(2) **Multi-institutional Promotion:** After piloting in 3 Shaanxi colleges, expand to 10 institutions by 2025 to form a CDIO education alliance.

(3) **Digital transformation:** Develop a "Virtual Pipefitter" training app for mobile installation simulations, complementing physical training.

This study's core contribution lies in validating a "simplified application" pathway for CDIO in vocational education—reducing project complexity, focusing on foundational competencies, and establishing progressive cultivation systems to implement advanced pedagogies under normal teaching conditions, thereby providing a replicable solution for cultivating innovative technical talents.

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