

Building a "Three-Stage and Seven-Loop" Teaching Closed Loop for the Automotive Electronic Control Technology Course Under Digital-Intelligence Empowerment

Xiaoxu Zhang*, Yuning Gong

School of Intelligent Manufacturing and Automotive Engineering, Chongqing Electronic Technology Vocational University, Chongqing, China

**Corresponding Author*

Abstract: The course of "Automotive Electronic Control Technology" in higher vocational education has long faced four major teaching pain points: abstract and difficult to understand electronic control logic, shallow control strategy analysis, insufficient system diagnostic accuracy, and weak awareness of standardized testing. In response to the above issues, this study has developed a "three-level seven loop" hybrid teaching model that is empowered by digital technology and rooted in the integration of "job, course, competition, certification, and thinking". Vertical integration of three stages: pre class preview, in class internalization, and post class expansion; Horizontally linking the seven teaching loops of "knowledge of the new, guidance, seeking truth, diligence, discernment, self-cultivation, and innovation". The ability to transition from "understanding electrical and difficult electrical control" to "understanding structure, understanding theory, precise inspection and diagnosis, and daring to serve the country" has been achieved, providing a replicable practical paradigm for the digital transformation and upgrading of electrical control courses in higher vocational education.

Keywords: Digital Intelligence Empowerment; Blended Online and Offline Teaching; Academic Portrait; Value Added Evaluation; Automotive Electronic Control Technology

1. Presentation of the Problem

With the deepening implementation of the "New Energy Vehicle Industry Development Plan (2021-2035)" and the "Intelligent Connected Vehicle Technology Roadmap 2.0", the automotive industry is accelerating its evolution towards electrification, intelligence, and networking, which imposes new requirements on

the integration of industry and education as well as science and education in higher vocational colleges [1]. The electronic control system has become the "central nervous system" of the entire vehicle, and the industry's demand for high-end skilled talents in digital debugging and accurate diagnosis of electronic control systems is becoming increasingly urgent. However, traditional electronic control course teaching faces four major pain points: firstly, the electronic control logic is abstract and difficult to understand. Pre class diagnosis shows that only 35% of students know ECU functions, and only 7% of students can distinguish fault codes from data streams. Students have a cognitive gap in the closed-loop logic of "perception decision execution feedback"; Secondly, the analysis of control strategies is superficial. 85% of students do not understand the principle of self diagnosis, are accustomed to "reading codes and exchanging parts", and lack causal analysis based on data flow; Thirdly, the diagnostic accuracy of the system is insufficient, and there is a lack of reverse reasoning thinking when facing multi system coupling faults; Fourthly, the awareness of standardized testing is weak, and the standardization of operations and self-learning ability need to be improved. At the same time, the Implementation Plan for National Vocational Education Reform and the Opinions on Promoting the High quality Development of Modern Vocational Education require the deep integration of information technology and education and teaching. The Overall Plan for Deepening the Reform of Education Evaluation in the New Era clearly proposes to improve result evaluation, strengthen process evaluation, and explore value-added evaluation. Artificial intelligence, virtual simulation and other technologies provide new ways to solve the above pain points. Based on this, the course team has undergone two rounds of teaching iterations

and constructed and practiced a "three-level seven loop" hybrid teaching model that empowers mathematics and intelligence [2].

2. Overall Teaching Design

2.1 Content Restructuring through PCCC Integration

The course accurately benchmarks the competency map of the "Automotive Electromechanical Maintenance Worker" position, seamlessly connects with the "Automotive Technology" competition rules of the National Vocational College Skills Competition [3], fully covers the 1+X Automotive Application and Maintenance (Intermediate) certificate examination points, and deeply linking 9 strategic cooperative enterprises in upstream, midstream, and downstream, translates the real fault work orders of enterprises including Changan Automobile and Huawei into four advanced project groups: "Cognitive foundation of automotive electronic control system cognition and OBD-II diagnosis, core challenge of engine electronic control system testing, comprehensive diagnosis and maintenance of automotive electronic control system, and expansion and improvement of electronic control automatic transmission system and safe driving electronic control system maintenance". It is further decomposed into 16 core tasks and 32 sub tasks, which is forming a content system of "project progression and task driven" to ensure skill improvement and safety driving. Value shaping resonates with the same frequency [4,5].

2.2 Precise Learning-Status Analysis Based on Multi-Source Data Fusion

Based on platforms such as Smart Campus, Learning Pass Online Platform, AI Analysis Report, and Enterprise Work Order Cloud, through the evaluation of process behavior data and the five elements of "teacher, student, assistant, enterprise, and AI", we conduct learning situation diagnosis from three dimensions: knowledge and skill foundation, cognitive and practical ability, and learning characteristics, and generate a "five dimensional ability portrait" of students. Data shows that students have significant characteristics of "understanding electrical engineering but difficult to control". 88% of students are proficient in using a multimeter to detect voltage

resistance, but only 7% of students can distinguish fault codes from data flow; 100% of students prefer task driven and simulation exercises, but have a fear of abstract control strategies; The hierarchical differentiation is obvious, with members of the Duxing team accounting for 35%, members of the Jingji team accounting for 51%, and only 14% of the Leading team. Based on this, the teaching focus is established as "Structural Principles and Standard Testing Processes of Electronic Control Systems", and the teaching difficulties are "Internalization of ECU Closed loop Control Strategies" and "Multi system Coupling Fault Traceability".

2.3 Determination of Three-Dimensional Teaching Objectives

Building a three-dimensional teaching objective around the core competencies of "knowledge construction, understanding theory, accurate examination and diagnosis, and daring to serve the country": connecting sensors at the knowledge level ECU、The working principle of the actuator; At the level of capability, solidify the standard operating procedures for decoders and oscilloscopes, and build reverse reasoning thinking for complex electronic control systems; In the context of the rise of domestic electronic control technology, it is necessary to cultivate outstanding craftsmen who possess both exquisite skills and patriotism in terms of quality [6,7].

3. Construction and Implementation of the "Three-Stage & Seven-Link" Teaching Closed Loop

3.1 Vertically Connecting Three Stages

In the pre class stage, based on enterprise work orders, real cases such as "engine idle shaking" are transformed into preview resource packages. The AI system generates a class "knowledge mastery heat map" based on historical data, accurately identifies common problems, and pushes differentiated learning resources to the third level echelon, embedding project cognition; In the new stage of understanding in class, rigidly embed the five step standardized homework process of "case guidance, theoretical truth-seeking, practical and realistic implementation, review and evaluation, and 6S organization", guide students to complete the transition from "reading fault codes" to "analyzing data streams",

and completely reverse the traditional misconception of "emphasizing codes and neglecting analysis"; In the post class exploration stage, we will coordinate with the enterprise's after-sales technical standard release team to consolidate tasks, and encourage students to internalize the diagnostic logic mastered in the classroom into stable job professional qualities.

3.2 Horizontally Linking Seven Nodes

In the "leading" stage, students simulate the role of service consultants, restore fault scenarios based on work order videos, define the logical boundaries of "perception, decision-making, and execution", and establish the core logic of "fault codes are the result, and data flow is the cause"; In the "seeking truth" stage, by comparing the information difference between static fault codes and dynamic data streams, a diagnostic path of "first looking at the stream, then reading the code, and then verifying" is formulated to break the cognitive misunderstanding of "code only theory"; In the "diligent implementation" stage, first conduct practical exercises and visualize closed-loop control logic on the electronic control simulation platform, and then connect to the real vehicle bench to carry out real working condition maintenance; In the "evaluation" stage, the AI scoring system performs millisecond level verification on the accuracy and logic of data stream retrieval; In the "organization" stage, benchmarking against the 6S management standards of enterprises, the system automatically verifies the tool's positioning, environmental organization and other normative items, and pushes real-time rectification prompts; In the "innovation" stage, differentiated job expansion tasks are pushed according to the team, shaping the professional skills of "electronic control doctors".

3.3 Tier-Specific Level-Clearing Mechanism

In response to the learning situation of "uneven foundation and differentiated levels", implement a "layered challenge" mechanism. The Duxing team completed structural principle cognition and electronic control component testing in the VR simulation cabin, and unlocked new tasks after completing the level; The precision technology team conducted fault code reading, data flow analysis, electronic control system diagnosis, and standardized SOP operations in the real-life training cabin; The leading team is directly connected to the school enterprise

cooperation project, tackling the comprehensive diagnosis and traceability of multiple faults. After class, the diligent team conducts intensive training by benchmarking 1+X exam points, the skilled team participates in school level fault diagnosis competitions, the leading team undertakes enterprise work order optimization, and consolidates knowledge structures in layers; The system automatically generates a "dynamic ability certificate" and records the growth trajectory of "basic standards, advanced abilities, and innovative breakthroughs" throughout the process, solving the problem of "high achieving students not having enough to eat and low achieving students not keeping up" in traditional teaching.

4. Digital-Intelligence Support: Full-Scenario and Dual-Track Evaluation

4.1 Virtual-Real Dual Spaces Visualizing Abstract Principles

Using VR virtual software and multi brand real car resources to create a learning scene that blends reality and virtuality, concretizing the invisible control logic of "perception, decision-making, and execution" into tangible and visible dynamic demonstrations; At the same time, 1:1 restoration of the enterprise's after-sales workshop was carried out, and enterprise mentors demonstrated the "seven step SOP" operation process in real person layers, achieving a "zero distance" connection between the learning environment and the job environment, effectively breaking the limitations of traditional practical training such as "invisible, inaccurate, and high-risk" [8].

4.2 AI Scoring Consolidating Standardized Operations

Relying on the AI operation evaluation system, the full process operation standardization of the decoder's "connection, vehicle selection, ECU loading, code reading, code clearing, and data stream reading" is verified at the millisecond level, and real-time feedback correction is provided to promote students' transition from "mechanical imitation" to "standardized operation", providing data-driven support for improving skill accuracy.

4.3 Dual-Track Value-Added Evaluation

Integrating the five evaluation subjects of "teacher, student, assistant, enterprise, and AI",

constructing a multidimensional integration pool covering knowledge, skills, literacy, and innovation: vertically connecting the three-level promotion path of "diligence, precision, and leadership", and horizontally linking the four-dimensional ability axis; Implement a dual level advancement of "basic compliance guarantee, innovative expansion empowerment", with the point threshold determining the unlocking permission for levels; Real time capture of four-dimensional data streams including online assessments, certificate mastery, work order implementation, and solution conversion, generating personal ability radar charts, accurately quantifying growth increments, and providing real-time feedback on students' internal drive [9,10].

5. Implementation Outcomes

5.1 Overall Improvement of Academic Performance

After two rounds of teaching practice, the final pass rate of students reached 100%, an increase of 13.9 percentage points compared to the previous academic year; The average class score has increased by 10.5 points compared to the previous class, and the excellence rate has increased by 13 percentage points; The proportion of students in the navigation team has increased from 13.9% to 30.2%; Based on the targeted assistance of "AI portrait+work order disassembly", we warn students to achieve a comeback in grades, with a maximum increase of 30 points for individual cases; The accuracy of circuit analysis is 98%, and the completeness of the system principle and OBD-II fault code structure description is 100%.

5.2 Significant Enhancement of Skill Accuracy and Job Fitness

The compliance rate of sensor waveform reading has increased from 68% to 97%, exceeding the industry benchmark by 9 percentage points; The accuracy of fault code reading has increased from 55% to 94%, and the accuracy of data flow analysis has reached 88%; 90% of students are proficient in performing standardized diagnosis throughout the entire process; 1+X certificate pass rate of 100%; The "Diagnostic Process Diagram of Electronic Control System" independently developed by students has been included in the after-sales manual of the enterprise. The operating procedures of 3

students have been included as training templates for new employees in the enterprise, and 15 students have obtained the qualification of enterprise internship, achieving a leap from "understanding principles" to "setting standards".

5.3 Simultaneous Improvement of Learning Motivation and Standardized Awareness

The average duration of students' self-study exceeds 550 minutes per person; The attendance rate and 6S compliance rate both reached 100%, and there were "zero violations" in electrical control maintenance throughout the year; Under the incentive of the "Advanced Points+Zeroing and Resurrection" mechanism, 6 warning students achieved self breakthrough, significantly enhanced their professional confidence, and realized the collaborative value-added of knowledge, ability, and literacy.

6. Reflection and Improvement

One is that simulation resources need to be expanded. The existing simulation cases mainly focus on traditional fuel vehicles, and there is a lack of electronic control resources for new energy vehicle models. The next step is to collaborate with enterprises to supplement the new energy electronic control simulation module, ensuring that the teaching content is synchronized and iterated with industry technology. Secondly, the mutual evaluation scale needs to be calibrated. In group peer evaluation, there is occasional phenomenon of "personal preference score". We will refine the scoring observation points and add a "mutual evaluation calibration" section to guide students to score according to specific standards and enhance the objectivity of the evaluation.

7. Conclusion

The essence of the "three-level seven loop" hybrid teaching model empowered by digital intelligence technology lies in using data to insight into learning situations, using scenarios to carry norms, and using evaluation to stimulate internal drive, ultimately leading to the cultivation of high-quality technical and skilled talents who understand structure and reason, conduct precise inspections and diagnoses, and dare to serve the country. Practice has proven that this model effectively solves the bottleneck of "understanding electrical engineering but difficult to control" in electrical control courses, achieving resonance between teaching supply

and industry demand, and providing reference for the digital transformation and upgrading of similar courses.

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