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A Study on the Application of the Dual-System Education Model in the Teaching of New Energy Vehicle Programs

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Abstract: With the rapid expansion of the new energy vehicle (NEV) industry, there is a growing shortage of frontline after-sales technicians capable of independently performing "three-electric system" (battery, motor, and electronic control) diagnostics and maintenance, as well as troubleshooting high-voltage faults in complete vehicles. However, many higher vocational institutions still rely on traditional teaching approaches in NEV-related programs. The curriculum is often disconnected from real-world repair practices in service workshops, practical training facilities are insufficient, and school-enterprise cooperation tends to be superficial, all of which directly undermine the quality of talent cultivation. Drawing on the German dual-system model of school-enterprise collaborative training, this study analyzes its advantages in skills-oriented education. Focusing on five key challenges in current teaching practice-curriculum design, practical training, teaching staff, school-enterprise collaboration, and instructional standards-this paper proposes an implementation pathway characterized by work-study alternation, co-teaching by dual-qualified instructors, and the integration of theory with hands-on practice. The study further explores context-sensitive strategies for adapting the dual-system model to the institutional conditions of Chinese higher vocational education. By aligning training with the competency requirements of automotive enterprises and localizing the dual-system approach, the proposed model can increase students' opportunities for independent practical operation, standardize high-voltage safety procedures, and shorten graduates' transition period into the workplace. The findings also provide a feasible reference for reforming NEV practical training in similar institutions.

Keywords: dual-system education, new energy vehicles (NEVs), practical training, school-enterprise collaborative education

1. Introduction

With the rapid development of the new energy vehicle (NEV) industry, the number of vehicles in operation has been increasing year by year, leading to a growing demand among automotive repair shops and authorized service centers for technicians proficient in high-voltage safety operations. As the primary providers of skilled talent, higher vocational institutions have generally established NEV-related programs. However, current teaching practices remain largely theory-oriented, with practical training hours significantly compressed. Students have limited opportunities to engage with newly released mass-produced vehicle models, and access to specialized high-voltage diagnostic equipment is often insufficient for independent operation.

On-campus teaching relies heavily on fixed textbooks, whose update cycles struggle to keep pace with rapid technological advancements in the industry. Emerging technologies such as 800V high-voltage platforms and wireless battery management systems (BMS) are rarely covered, and there is a clear gap between simplified textbook cases and real-world workshop repair orders. Consequently, enterprises are often required to invest additional resources in pre-employment retraining for new graduates, thereby increasing labor costs.

The German dual-system model, developed through long-term practice, has established a collaborative school-enterprise talent cultivation framework. Its structure-characterized by small-group practical training and alternating periods of study between school and enterprise-aligns well with the NEV field's emphasis on operational and hands-on competence. By adapting classroom instruction and practical training arrangements based on existing institutional resources, it is possible to effectively address key challenges such as limited hands-on opportunities and the misalignment between academic training and industry needs.

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2. Analysis of the Advantages of the German Dual-System Education Model

A defining feature of the German dual-system of vocational education and training is the joint responsibility of schools and enterprises in talent development. Students simultaneously assume dual roles as learners in educational institutions and apprentices in enterprises. The two learning environments-classroom and workshop-have clearly differentiated yet complementary functions, forming a closed-loop training system.

Educational institutions are responsible for establishing a comprehensive theoretical foundation. In NEV programs, classroom instruction focuses on the structure of the three-electric systems (battery, motor, and electronic control), high-voltage safety regulations, and principles of electronic control systems, thereby strengthening students' theoretical knowledge. In contrast, partner enterprises provide skill training based on real repair workshops, commercially available NEVs, and original manufacturer diagnostic equipment. Training materials are derived directly from actual repair work orders, ensuring that learning contexts closely mirror real working environments.

This model strictly controls the size of practical training groups to ensure that each student can independently complete disassembly, inspection, and diagnostic procedures. In addition, the six-step instructional method is employed to break down practical tasks, balancing theoretical understanding with hands-on practice. Furthermore, Germany has established a unified vocational qualification assessment system in which written theoretical examinations and workshop-based practical tests are conducted concurrently. Over the course of training, students continuously develop standardized operational awareness and a strong sense of professional responsibility. This approach fundamentally addresses the long-standing disconnect between theory and practice in traditional vocational education and demonstrates high suitability for fields requiring strict operational standards, such as high-voltage maintenance and full-vehicle fault diagnosis (Xu, 2026).

3. Existing Problems in the Teaching of New Energy Vehicle Programs

3.1 Curriculum design detached from work orders and imbalanced integration of theory and practice

In many higher vocational institutions, the curriculum for NEV programs is still largely based on outdated textbooks, which are revised infrequently and fail to adequately reflect mainstream technological developments in the industry. Classroom case studies are often simplified and rarely incorporate real repair work orders or complex, multi-system fault scenarios from service workshops. Instructional time allocation tends to favor theoretical teaching, while essential hands-on practices-such as battery pack diagnostics, motor fault troubleshooting, and full-vehicle insulation testing-are mostly demonstrated by instructors rather than performed independently by students. As a result, students have limited opportunities to complete the full workflow of receiving a vehicle, diagnosing faults, performing repairs, and conducting post-repair inspections. This imbalance between theory and practice contradicts the core principle of the dual-system model, which emphasizes their parallel integration. Consequently, students tend to rely on rote memorization of abstract concepts such as electronic control and thermal management, without developing the diagnostic reasoning required in real workshop contexts. Upon entering the workforce, they often struggle to handle complex faults independently, requiring enterprises to provide additional pre-employment training.

3.2 Insufficient supply of practical training resources and limited hands-on opportunities

The procurement and maintenance costs of NEV training vehicles and high-voltage diagnostic equipment are relatively high. Due to budget constraints, most on-campus training bases are equipped with only a limited number of modified internal combustion engine vehicle platforms, while up-to-date pure electric and hybrid training vehicles are scarce. Essential equipment-such as insulation testers, battery balancing systems, and original manufacturer diagnostic tools-is often insufficient to meet the standards of real service workshops. With typical class sizes of around 40 students, it is common for more than ten students to share a single vehicle and a set of equipment during practical sessions. This significantly reduces individual hands-on time, leaving many students as passive observers. In contrast, the German dual-system model imposes strict limits on training group sizes to ensure adequate operational practice for each learner. Under current conditions, most domestic institutions face challenges in meeting such standards due to limitations in facilities and hardware resources (Xu, 2025). As a result, students lack repeated exposure to high-voltage operations, making it difficult to develop proficiency in safety procedures and fault diagnosis, thereby compromising the effectiveness of practical training.

3.3 Limitations in teaching staff competence and insufficient dual-qualification capacity

Most professional instructors in vocational institutions enter teaching positions directly after graduation and primarily focus on theoretical instruction. Many institutions lack structured mechanisms for regular industry placement, making it difficult for teachers to engage in hands-on practice within enterprise service workshops. Consequently, some instructors have limited familiarity with current mainstream vehicle electronic control systems, original diagnostic equipment, and typical fault-handling procedures for new-generation three-electric systems. This gap becomes particularly evident when guiding students through complex practical training tasks.

On the other hand, enterprise technicians possess extensive hands-on experience with real vehicles but often lack formal pedagogical training in vocational education. They may be unfamiliar with instructional design principles, such as task decomposition and scaffolded learning progression, and their teaching tends to rely on traditional one-way apprenticeship demonstrations rather than standardized and systematic training approaches. These two groups of instructors exhibit complementary strengths but also clear limitations. However, the absence of sustained collaborative teaching and joint research mechanisms hinders the realization of the dual-system goal of coordinated instruction by academic teachers and enterprise mentors.

3.4 Superficial school-enterprise cooperation and the absence of work-study alternation

In most cases, cooperation between vocational institutions and NEV enterprises or authorized service centers remains superficial, limited to short-term visits or final-stage internships. Enterprises rarely participate in core educational processes, such as curriculum design, development of training modules, or the formulation of training tasks. Furthermore, there is a lack of sustained joint teaching and research mechanisms between schools and enterprises.

The overall teaching cycle is dominated by on-campus instruction, with little implementation of phased and cyclical work-study alternation. Students typically enter enterprise workshops only for a short period near graduation, while their earlier learning experiences are confined to campus training environments. Such fragmented and short-term cooperation fails to establish the dual-system framework of parallel theoretical instruction in schools and practical skill development in enterprises. As a result, educational resources from both sides remain disconnected, and the intended synergy between theory and practice cannot be effectively realized.

3.5 Enterprise training overemphasizing practice at the expense of theory and imbalanced training standards

In some cooperating service workshops, the primary objective of accepting student trainees is to address the backlog of repair tasks. Consequently, training focuses heavily on basic, standardized operations such as component disassembly and replacement, with limited attention to underlying theoretical knowledge, including battery thermal management, motor electromagnetic control, and high-voltage protection systems.

Students tend to rely on mechanical repetition of procedures without understanding the electrical and structural principles behind faults. When encountering new vehicle models or complex, less common fault scenarios, they often lack the ability to independently analyze causes and complete systematic diagnostics. This practice-oriented but theory-neglecting approach contradicts the core principle of the dual-system model, which emphasizes the equal importance of theoretical knowledge and practical skills. While such training may enable students to quickly acquire basic operational skills in the short term, it restricts their long-term professional development and makes it difficult to cultivate high-quality technical personnel capable of independent fault diagnosis and comprehensive system analysis (Chen, 2025).

4. Application Strategies of the Dual-System Education Model in New Energy Vehicle Programs

4.1 Reconstructing the curriculum system based on work orders and balancing theoretical and practical instruction

The core principle of dual-system education lies in aligning theoretical learning with authentic occupational tasks while avoiding purely theoretical instruction detached from production practices. This principle provides an important direction for optimizing the curriculum of NEV programs. Vocational institutions should collaborate with local NEV enterprises and authorized service centers to arrange phased industry placements for instructors, during which they collect authentic repair work orders related to power batteries, motor controllers, and full-vehicle high-voltage maintenance. These work orders can then be classified into task modules according to maintenance, repair, and vehicle diagnosis requirements. By applying the six-step instructional method, complex repair tasks can be transformed into progressive practical training projects with increasing levels of difficulty.

Following the dual-system approach to training hours, institutions should restructure curriculum arrangements to reduce the excessive proportion of theoretical courses and establish a three-stage integrated teaching model consisting of theoretical instruction, on-campus simulated practice, and enterprise-based work-order training. During on-campus teaching of theoretical knowledge, such as high-voltage safety regulations and three-electric system structures, students should simultaneously undertake practical tasks including high-voltage platform disassembly, basic component testing, and fault simulation exercises, enabling them to immediately verify theoretical concepts through practice. During enterprise training, students participate as apprentices and undertake complete repair work orders, independently completing the entire workflow from vehicle reception, fault diagnosis, and component inspection to safety reinspection (Liu et al., 2024).

Schools and enterprises should jointly revise practical training manuals by embedding frequently occurring workshop cases, such as battery balancing failures and vehicle insulation faults, into corresponding theoretical chapters. This approach enables abstract knowledge related to electronic control and thermal management systems to be directly connected with real vehicle fault scenarios. Consequently, it addresses the traditional separation between theoretical teaching and practical operation and implements the dual-system principle of “learning through application.”

4.2 Sharing practical training resources between schools and enterprises and implementing small-group training

The German dual-system model strictly regulates practical training group sizes, generally maintaining class sizes below 30 students and limiting practical training groups to no more than six learners. Such arrangements ensure that each apprentice has sufficient opportunities to independently operate vehicles and equipment, providing an effective solution to the shortage of training resources in vocational institutions.

Vocational institutions should establish long-term cooperation agreements with enterprises for mutual sharing of equipment and training facilities and divide practical learning environments according to their respective advantages. On-campus training bases can focus on introductory activities, such as high-voltage component disassembly and basic insulation testing, while enterprise workshops can provide advanced training, including full-vehicle high-voltage operations and real vehicle fault diagnosis. By utilizing idle production periods and non-peak service hours, enterprises can open workshop positions for student training through flexible scheduling and rotation arrangements.

Schools and enterprises can jointly share high-cost training resources, including new pure electric and hybrid vehicle training platforms, high-voltage insulation testing instruments, battery balancing equipment, and original manufacturer diagnostic systems. Costs associated with equipment procurement, calibration, and maintenance can be jointly undertaken, significantly reducing the financial burden on individual institutions. Based on shared resources, small-group practical training requirements can be fully implemented, with each group equipped with dedicated training vehicles and equipment. Through collaborative guidance from school instructors and enterprise technicians, this approach can fundamentally transform the previous situation in which numerous students shared limited equipment and most learners remained passive observers, thereby ensuring stable implementation of individualized and hands-on training (Li, 2024).

4.3 Establishing a dual-qualified teacher development pathway and promoting collaborative teaching

Under the dual-system model, students simultaneously assume the identities of institutional learners and enterprise apprentices. Therefore, teaching responsibilities must be jointly undertaken by academic instructors and enterprise technicians. A single teaching team is insufficient to complete the entire talent cultivation process.

Vocational institutions should establish systematic enterprise-based professional development programs, requiring NEV instructors to undertake one- to two-month full-time placements in partner enterprises' after-sales service departments each semester. During these placements, instructors should work alongside frontline technicians in handling three-electric system maintenance and vehicle fault diagnosis tasks while becoming familiar with the electronic control logic of new vehicle models and standardized procedures for original diagnostic equipment. This process can effectively compensate for instructors' limited practical experience and support the development of dual-qualified teaching capacity.

For experienced enterprise technicians, institutions should regularly organize pedagogical training programs focusing on vocational teaching methods, including practical task decomposition, classroom facilitation, high-voltage safety management, and differentiated student guidance. Such training can address the common limitation that enterprise technicians possess strong technical expertise but insufficient instructional skills (Wang et al., 2024).

Schools and enterprises should establish joint teaching and research teams to collaboratively identify key and difficult training points, develop standardized practical training guides and work-order task sheets, and unify high-voltage operation standards. Through the implementation of a dual-mentor teaching system, academic instructors focus on theoretical frameworks and underlying principles, while enterprise technicians provide real vehicle demonstrations and practical fault diagnosis guidance. Both groups participate in student consultation, error correction, and formative assessment, thereby improving teaching quality through complementary expertise.

4.4 Developing a work-study alternation mechanism and conducting joint curriculum development

A continuous and cyclical work-study alternation mechanism represents one of the most fundamental distinctions between the dual-system model and traditional graduation internships. Through alternating learning experiences between educational institutions and enterprises, students can simultaneously develop theoretical knowledge and occupational skills, avoiding fragmentation between academic learning and practical training.

Considering the learning characteristics of NEV programs and the operational schedules of enterprise workshops, a cyclical training model can be designed, consisting of "two weeks of intensive theoretical learning on campus followed by three weeks of enterprise-based work-order practice." During the campus phase, students systematically study professional theories and high-voltage safety standards. During the enterprise phase, they participate in authentic repair activities as apprentices. The two learning environments are seamlessly connected, allowing classroom knowledge to be rapidly transferred into practical workplace applications.

Schools and enterprises should jointly establish professional development committees involving enterprise technical directors, after-sales service managers, program leaders, and key academic staff. These stakeholders should participate throughout the processes of revising talent cultivation plans, developing curricula, and updating practical training projects. Industry standards for high-voltage maintenance, vehicle inspection procedures, and occupational competency requirements should be directly transformed into teaching content, preventing institutions from developing curricula without sufficient connection to industry practices (Li, 2021).

Enterprises should also participate deeply in students' formative assessment. Following the assessment framework of the German dual-system vocational qualification system, evaluation should consist of three components: theoretical examinations, on-campus platform-based practical tests, and enterprise work-order assessments. Enterprise technicians should independently evaluate workshop performance, and these results should be incorporated into students' overall academic assessment. Through full participation of both schools and enterprises in work-study alternation, a sustainable training platform featuring joint management, teaching, and assessment can be established, replacing previous superficial cooperation models where enterprises only accepted graduates for short-term internships.

4.5 Establishing unified school-enterprise training standards and integrating theory with practice

The dual-system approach emphasizes that theoretical learning and practical training are equally important and mutually indispensable. To address the common limitation among cooperating enterprises of focusing only on operational procedures while neglecting underlying principles, schools and enterprises should jointly develop standardized dual-system practical training guidelines specifically designed for NEV programs.

These guidelines should clearly define the theoretical knowledge corresponding to each practical task and specify the required proportion and key contents of theoretical explanation within practical training. When enterprise technicians conduct training activities such as battery pack disassembly, motor maintenance, and high-voltage testing, they should not merely demonstrate operational procedures. Instead, they should simultaneously explain fundamental concepts related to battery thermal management, motor electromagnetic control, and vehicle insulation protection based on actual vehicle components. This enables students to understand the underlying mechanisms of faults rather than simply memorize repair procedures (Yue, 2017).

On-campus theoretical courses should incorporate repair work-order cases encountered during enterprise training and use students' practical experiences to explain complex theoretical concepts, thereby creating a two-way connection between theory and practice. Furthermore, schools and enterprises should establish unified assessment standards that include theoretical understanding, independent fault analysis ability, standardized operation skills, and professional safety awareness as core evaluation criteria. By reducing excessive emphasis on isolated indicators such as operation speed, the assessment system can achieve a balance between knowledge development and practical competence, fully implementing the dual-system principle of integrated theoretical and practical education.

5. Conclusion

In summary, positions related to NEV high-voltage maintenance and three-electric system fault diagnosis require technicians to possess not only strong practical operational skills but also a solid foundation of underlying theoretical knowledge. The traditional teaching model that relies solely on classroom-based instruction is increasingly unable to meet current industry requirements for skilled talent development.

Centered on collaborative school-enterprise talent cultivation, the German dual-system education model provides a comprehensive training framework characterized by work-study alternation, small-group practical training, dual-mentor instruction, and equal emphasis on theoretical knowledge and practical competence. This model offers targeted solutions to the major challenges currently faced by NEV programs in five key areas: curriculum design, practical training resources, teaching staff development, school-enterprise cooperation, and instructional standards.

By adapting the core principles of the dual-system model to the operational conditions of Chinese higher vocational institutions and available local enterprise resources, a localized training approach can be developed. Through five practical measures-including work-order-based curriculum reconstruction, shared school-enterprise training resources, dual-qualified teacher development pathways, phased work-study alternation, and unified school-enterprise teaching standards-the proposed approach can effectively increase students' opportunities for independent practical operation, establish standardized high-voltage safety practices, and significantly improve graduates' occupational adaptability.

This study provides a practical reference for the reform of NEV practical training and the development of industry-oriented talent cultivation models in similar vocational institutions.

Conflict of Interest

The author declares that she has no conflicts of interest in this work.

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