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A Study on the Development and Implementation of a Project-Based Learning Model for Hybrid Vehicle Repair Technology Training at Ho Chi Minh City College of Industry and Trade

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ABSTRACT: The global shift towards sustainable transportation technologies has spurred the rapid proliferation of electrified vehicles (xEVs), wherein hybrid technology serves as a strategic bridge. In Vietnam, the growing popularity of hybrid vehicles presents a significant challenge to the vocational education and training (VET) system: the existence of a competency gap between traditional training curricula and the practical demands of the industry. Conventional pedagogical methods, which focus on content delivery and guided practice, have proven ineffective in cultivating the higher-order thinking skills required to diagnose and resolve issues within the complex mechatronic systems of hybrid vehicles.This paper presents an action research study on the design, implementation, and evaluation of the "Hybrid-Pro" Project-Based Integrated Learning Model at the Faculty of Mechanical Engineering, Ho Chi Minh City College of Industry and Trade. The model is founded on the theoretical framework of Project-Based Learning (PBL), integrated with the principles of Kolb's Experiential Learning Theory and Vygotsky's Social Constructivist Theory. The core of this model places students in the role of authentic technicians, tasking them with resolving project-based, simulated complex faults on Toyota Prius vehicles.The study details the model's three-stage structure: (1) Project Initiation & Problem Analysis, (2) Guided Research & Repair Implementation, and (3) Conclusion, Critique & Product Handover. Quantitative and qualitative results after a two-year implementation period indicate that the "Hybrid-Pro" model has significantly improved learning outcomes. Specifically, 100% of participating students mastered and adhered to international high-voltage safety protocols, and their complex fault diagnosis competency increased by 45% compared to a control group taught via traditional methods. Qualitative analysis revealed marked development in students' teamwork skills, critical thinking, and academic self-confidence. This paper not only provides a validated pedagogical model but also offers systemic recommendations for replicating and scaling up active learning methodologies in the context of Industry 4.0.

Keywords: Hybrid vehicles, project-based learning, technical pedagogy, diagnostic competency, high-voltage safety, College of Industry and Trade.

I. INTRODUCTION

The global automotive industry is in the midst of a paradigm shift, driven by the twin forces of increasingly stringent emissions regulations and the rapid advancement of electrification technology. Within this movement, electrified vehicles (xEVs), with hybrid technology as the vanguard, have become an irreversible trend. In Vietnam, this trend is clearly reflected in reports from the Vietnam Automobile Manufacturers' Association (VAMA), which show that hybrid vehicle sales have recorded an average annual growth rate exceeding 50% during the 2020-2024 period. This rapid proliferation, while a positive signal for the greening of transportation, poses a formidable challenge to the after-sales service sector and, most critically, to the vocational education and training (VET) system.

As a reputable technical training institution with a history of nearly 50 years, Ho Chi

Minh City College of Industry and Trade (HITC) has always embraced a pioneering role in supplying a high-quality workforce to society. The college's Faculty of Mechanical Engineering, through its extensive partnership programs with major corporations such as Mercedes-Benz, VinFast, and Suoi Tien Ford, has long been a trusted name in automotive training. However, when faced with the complexity of hybrid technology—specifically Toyota's Hybrid Synergy Drive (HSD) system, a sophisticated mechatronic assembly [1]—the institution confronts significant challenges. This complexity demands that technicians move beyond isolated mechanical or electronic knowledge to possess systems thinking—a core competency for analyzing the interactive, causal relationships between components.

The disconcerting reality is that the traditional training model, designed within the conventional paradigm of a content-based approach, is revealing clear limitations. Students learn subjects in a fragmented manner; hands-on activities are often confined to "cookbook labs," where they follow step-by-step instructions to reach a predetermined outcome [2]. While this method provides foundational knowledge, it fails to cultivate the competencies that the industry critically needs: the ability to diagnose complex malfunctions, creative problem-solving skills, and, paramountly, the ability to work with absolute safety on high-voltage electrical systems.

The direct consequence is a widening "competency gap" between the institution's graduate outcomes and the practical requirements of authorized service centers. The situation where graduates, including high-achieving ones, still require extensive retraining by employers not only wastes societal resources but also diminishes the competitiveness of the workforce itself.

Recognizing this profound issue and embracing its responsibility as a leading training provider, the HITC Board of Rectors and the Faculty of Mechanical Engineering have identified the fundamental reform of teaching and learning methods as a strategic and urgent imperative. This has led to the formulation of a central research question: How can a pedagogical model be developed to break from the confines of traditional teaching methods, enabling students at HITC to effectively construct the necessary competencies to confidently master complex hybrid vehicle technology?

This paper, through an action research study systematically implemented within the college's own workshops, will present a detailed account of the development, application, and evaluation of a new instructional model based on Project-Based Learning (PBL), with the aim of providing a compelling answer to this research question.

Fig.1. The complexity of hybrid technology – the primary subject of the study.

II. LITERATURE REVIEW AND THEORETICAL FRAMEWORK

2.1. Analysis of the Technical Structure and Competency Requirements of Hybrid Technology

The Toyota Hybrid Synergy Drive (HSD) system, a prime example of a series-parallel hybrid system, demands a broad spectrum of competencies from technicians. These can be categorized into three main groups:

Competency in High-Voltage Electrical and Electronic Systems: This includes knowledge of the architecture and operating principles of Ni-MH or Li-ion batteries, procedures for diagnosing battery State of Health (SOH), and the principles of inverters and DC-DC converters. Of utmost importance is the practical ability to execute high-voltage safety procedures flawlessly, including system de-energization, the use of insulated tools, and adherence to international standards for personal protective equipment (PPE) [3].

Competency in Mechatronic and Control Systems: This focuses on the interaction between the Atkinson-cycle internal combustion engine, the planetary gear-based power split device (e-CVT), and the two motor-generators (MG1/MG2). Technicians must be able to read and analyze the data stream from diagnostic scan tools to comprehend the power flow across all vehicle operating modes [1].

Competency in Holistic Diagnostic Reasoning: This is a higher-order competency that

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requires technicians to integrate knowledge from the two preceding groups to resolve complex faults, such as a "Check Hybrid System" warning. This fault can originate from dozens of potential causes, ranging from a single faulty battery cell and a malfunctioning inverter cooling system to a communication error on the CAN bus network [4].

2.2. Theoretical Foundations of Project-Based Learning (PBL)

PBL is not a new methodology, but its systematic application in VET in Vietnam remains limited. According to the Buck Institute for Education (BIE), PBL is an instructional method in which students gain knowledge and skills by working for an extended period to investigate and respond to an authentic, engaging, and complex question, problem, or challenge [5].

The "Hybrid-Pro" model is constructed upon the integration of three foundational learning theories:

David Kolb's Experiential Learning Theory: Kolb posits that effective learning is a four-stage cycle: (1) Concrete Experience (CE), (2) Reflective Observation (RO), (3) Abstract Conceptualization (AC), and (4) Active Experimentation (AE) [6]. The PBL model creates an ideal environment for students to complete this cycle: they directly "experience" faults (CE), discuss and "reflect" on diagnostic steps (RO), link real-world phenomena to theoretical knowledge to "conceptualize" (AC), and finally, "experiment" with their proposed repair solutions (AE).

Fig.2. Advanced diagnostic tools in a learning environment.

Lev Vygotsky's Social Constructivist Theory: Vygotsky argued that knowledge is constructed through social interaction. His concept of the "Zone of Proximal Development" (ZPD) describes the gap between what a learner can achieve independently and what they can achieve with guidance from a "More Knowledgeable Other" (MKO) [7]. In the PBL model, the instructor and fellow team members act as MKOs, providing scaffolding that enables each individual to overcome challenges and reach new levels of understanding.

Problem-Based Learning: A subset of PBL, this approach focuses on using "ill-structured problems" as the starting point for the learning process [8]. The faults on a hybrid vehicle are precisely such problems; they lack a single, straightforward solution and require students to conduct their own inquiry and research to formulate a resolution.

International research has consistently demonstrated the efficacy of PBL in engineering education. For instance, a study at Aalborg University (Denmark) found that engineering students trained via a PBL model exhibited superior problem-solving and teamwork skills compared to those in traditional programs [9].

III. THE "HYBRID-PRO" PROJECT-BASED LEARNING MODEL: DESIGN AND METHODOLOGY

This study is an action research project conducted over four consecutive semesters at the Faculty of Mechanical Engineering, involving 80 final-year students. A control group of 40 students followed the traditional curriculum.

3.1. Model Design

The "Hybrid-Pro" model is structured into three main phases, spanning 10 weeks.

Phase 1: Project Initiation – "Client Intake" (2 weeks)

Objective: To transition students from the role of passive learners to that of proactive problem-solvers.

Fig.3. A close-up of hybrid technology - the heart of the training program.

Implementation:

Task Assignment: The instructor, acting as a "Service Advisor," prepares "Repair Orders" with realistic fault scenarios pre-simulated on Toyota Prius vehicles (e.g., "Vehicle displays 'Check Hybrid System' warning, battery cooling fan is abnormally loud," or "Poor fuel economy, engine runs continuously even at idle").

Team Formation: Students are organized into "Technical Teams" (4-5 members per team), ensuring a mix of academic abilities within each group.

Project Planning: Each team receives a project and is tasked with first researching technical documentation (wiring diagrams, repair manuals) and creating a detailed "Diagnostic Plan." This plan must include: (a) initial hypotheses regarding the cause of failure; (b) proposed testing procedures; (c) a list of necessary tools and equipment; (d) task assignments for each team member; and, most importantly, (e) a "Safety Risk Assessment" and corresponding preventive measures.

Phase 2: Guided Research & Repair Implementation – "Workshop Action" (6 weeks)

Objective: To develop diagnostic competency, practical skills, and teamwork through an iterative cycle of "action-reflection."

Implementation:

Plan Execution: Teams proceed with the diagnostic steps outlined in their plans. The instructor does not intervene directly but acts as a facilitator, continually using Socratic questioning to stimulate critical thinking: "What does this Freeze Frame data tell you about the conditions when the fault occurred?", "Why is the voltage of cell block #5 lower than the others?", "If the test results are not what you expected, what is your next step?"

Technical Debriefings: At the end of each week, teams present their progress, challenges encountered, and new findings. This is a core activity where social constructivist learning occurs [7]. Other teams pose critical questions and share experiences from their own projects, fostering a vibrant peer-to-peer learning environment.

Just-in-Time Lectures: Instead of regularly scheduled lectures, the instructor delivers 30-45 minute "mini-lectures" to address theoretical concepts that multiple teams are struggling with, such as "An in-depth analysis of the electric inverter coolant pump's operation." This approach ensures that theory is immediately linked to practice, making the knowledge "live" and meaningful.

Phase 3: Conclusion, Critique & Product Handover – "Vehicle Delivery" (2 weeks)

Objective: To systematize acquired knowledge, develop presentation skills, and conduct a comprehensive assessment of student competencies.

Implementation:

Finalization and Verification: After completing the repair, the team must conduct road tests and re-check all hybrid system operating parameters with a scan tool to confirm the issue has been fully resolved.

Project Portfolio Development: Each team compiles a final report documenting the entire process, from initial reception to the completed repair, supported by evidence (photos, videos, scan tool data).

Project Defense: Each team has 30 minutes to present and 15 minutes to answer questions from a review panel (comprising the instructor and representatives from other teams). This defense simulates a lead technician explaining a complex repair case to a workshop manager.

Self and Peer Assessment: Students are required to evaluate their own contributions and those of their teammates, fostering a sense of individual and collective responsibility.

IV. RESULTS AND DISCUSSION

4.1. Quantitative Results

Safety Compliance Competency: 100% of the students in the experimental group passed a practical examination on the high-voltage system de-energization and re-energization procedure (compared to 75% in the control group).

Diagnostic Competency: In a final examination featuring a completely new fault, 85% of the experimental group students correctly isolated and identified the root cause within the allotted time. The success rate for the control group was 40%.

Academic Performance: The average grade in major-specific modules for the experimental group was 18% higher than that of the control group.

4.2. Qualitative Results

In-depth interviews and anonymous surveys revealed positive shifts in students' attitudes and perceptions:

Confidence and Proactiveness: Student A shared, "I used to be terrified of seeing a hybrid warning light. But after completing the project myself, I understand that every fault has its logic. Now, I feel confident I can handle them."

Collaboration Skills: Student B noted, "Teamwork taught me how to listen to others. There were times our whole group was stuck, but when we brainstormed, everyone's ideas combined eventually showed us the way forward. That never happens when studying alone."

Theory-Practice Integration: Student C remarked, "Project-based learning is very different. When I face a real problem, I have to go back to the books, search for documents online. Only then do I truly understand why the formula is what it is, or why the wiring diagram is drawn that way. The knowledge is much more meaningful and easier to retain."

4.3. Discussion

The results of this study align with global findings on the effectiveness of PBL in technical education [9], [10]. The "Hybrid-Pro" model succeeded because it addressed the inherent weaknesses of traditional pedagogy. By placing students at the center of an authentic problem, the model fostered an intrinsic motivation to learn. Instead of learning for an exam, students learned to solve a problem.

The integration of "Technical Debriefings" and "Just-in-Time" lectures created a continuous loop between experience and reflection, helping students not only to accumulate discrete experiences but also to systematize them into theoretical knowledge, perfectly mirroring Kolb's learning cycle [6]. The collaborative environment, supported by the instructor, created a safe "Zone of Proximal Development" where students dared to experiment, dared to fail, and learned from their mistakes [7].

V. CONCLUSION AND RECOMMENDATIONS

This research has demonstrated that the implementation of the "Hybrid-Pro" Project-Based Learning model is an effective solution for enhancing the quality of human resource training in the automotive technology sector to meet the demands of hybrid vehicle technology. The model not only helps students master specialized knowledge and skills but also holistically develops the higher-order thinking and soft skills essential for their future careers.

For this model to be replicated and sustainably developed, the authors propose the following recommendations:

For Institutional Management and Leadership: A shift in the managerial mindset is required, embracing flexibility in scheduling and curriculum structure to accommodate the unique nature of project-based learning. Investment priority should be given to dedicated "project-based workshops" equipped with modern tools and, most importantly, actual training vehicles.

For Faculty Development: Professional development programs must be organized to train instructors in transitioning from the role of a "knowledge transmitter" to that of a "designer, facilitator, and supporter" of the learning process. This is the key determinant of the model's success.

For Technology Integration: Future research could explore the integration of Virtual Reality (VR) and Augmented Reality (AR) into Phase 2 of the model. Students could use AR glasses to view overlaid information about components or energy flows while working on a real vehicle, enhancing both efficiency and safety [11].

For Industry-Academia Linkage: A more robust collaborative mechanism should be established with corporations like Toyota Vietnam, allowing student "projects" to be based on real-world "cases" encountered by dealerships. Furthermore, experienced industry technicians should be invited to participate in the project review panels.

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