Virtual-Real Integration and AI-Empowered Curriculum Reform for Higher Vocational SLAM Navigation

Yang Liu*

Shandong Institute of Commerce and Technology, Jinan, 250103, China

*302966352@qq.com

Abstract. To address the critical problems of misaligned textbooks, difficult environment deployment, and inefficient code teaching in higher vocational SLAM navigation courses, this paper proposes a systematic teaching reform. Guided by the integration of “job, course, competition, and certificate” and following the principles of virtual-real integration and theory-practice blending, a project-based digital textbook and a general simulation case library are developed through school-enterprise collaboration. The textbook adopts an “algorithm usage over algorithm principle” approach, with line-by-line code annotations and progressive task design. A dual-mode development environment (VMware virtual machine and portable hard drive) is constructed, significantly lowering the deployment threshold. AI-assisted programming is integrated into a three-stage teaching method of “understanding, reading, and transfer,” replacing the traditional code-copying approach. Three years of practice show that the case reproduction success rate increases from 56.4% to 88.7%, the comprehensive task completion rate increases from 58.7% to 81.9%, and students’ learning interest and competition achievements improve significantly. This reform provides a low-cost, high-effectiveness, and replicable paradigm for higher vocational robotics courses.

Keywords: SLAM Navigation; Teaching Reform; Virtual-Real Integratio

1 Introduction

Grounded in constructivism, OBE, and the CDIO engineering education model, this study establishes a systematic teaching framework centered on the core competency of independent SLAM system deployment. The curriculum is structured into a cohesive engineering practice chain: environment deployment, robot modeling, simulation, and practical verification [1]. However, current vocational SLAM education faces four critical challenges: outdated textbooks that heavily rely on specific hardware and algorithmic theory, leading to high costs; an inefficient "demonstration-copying" pedagogy that neglects logical understanding and yields a low case reproduction success rate (56.4%); complex development environments incompatible with standard Windows-based labs;

Z. Ge et al. (eds.), *Proceedings of the 2026 6th International Conference on Education, Information Management and Service Science (EIMSS 2026)*, Atlantis Highlights in Computer Sciences 25,
https://doi.org/10.2991/978-94-6239-766-8_18

and fragmented course content with over 30% redundancy in ROS basics. These systemic issues severely hinder teaching effectiveness and students' practical skill acquisition.

2 Teaching Reform Scheme Design

2.1 Overall Design Approach

Guided by the integration of "job, course, competition, and certificate"[2] and following the principles of "virtual-real integration, AI empowerment, and project-driven approach," systematic reforms are carried out from four dimensions: textbook, environment, pedagogy, and model (see Fig. 1) [3].

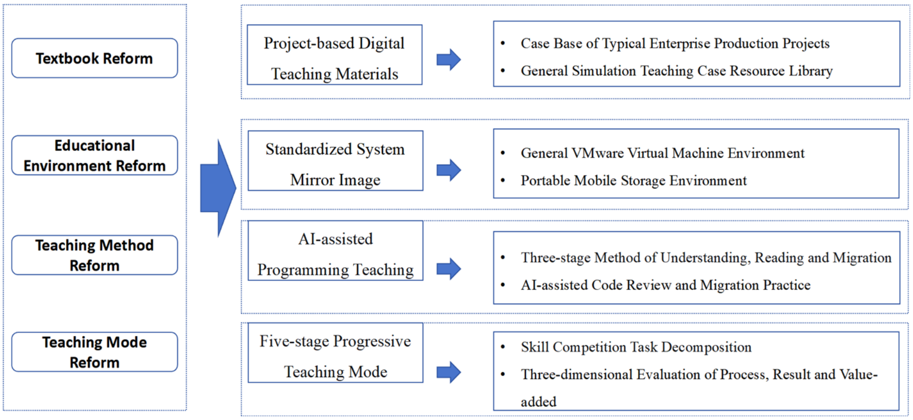

Fig. 1. Overall Framework of the "Virtual-Real Integration, AI-Empowered" Teaching Reform for SLAM Navigation Course.

2.2 Textbook Development: Project-based Digital Textbook and Supporting Simulation Cases

Enterprise engineers and industry experts were jointly engaged to restructure the textbook content in accordance with the requirements of "job, course, competition, and certificate" integration.

Finally, the textbook adopts a "project-led, task-driven" structure, featuring a total of 9 projects and 36 tasks, as shown in Table 1. Each task is accompanied by complete runnable code, line-by-line annotations, and variant exercises, omitting mathematical derivations of algorithms and emphasizing "algorithm usage and parameter tuning"[4].

This reform developed a simulation case library that does not rely on specific hardware platforms, with all cases validated in the Gazebo simulation environment [5]. The case library covers three levels of competency: basic motion control simulation (e.g., speed command response, trajectory tracking), module-level sensor simulation (data reading and parsing of LiDAR, camera, odometry), and SLAM mapping and navigation simulation [6] (supporting mapping and navigation validation with algorithms such as gmapping, cartographer, and hector_slam) [7].

Table 1. Styles available in the Word template.

Module	Project	Number of Core Tasks	Class Hours
Creation of Intelligent Robot Simulation Platform	1: System Environment Deployment 2: Simulation Model Construction 3: Indoor Simulation Environment Setup 4: Trajectory Motion Control Simulation	13	18
Perception, Interaction & Autonomous Navigation Simulation	5: Intelligent Robot Voice Interaction Practice 6: Intelligent Robot Environment Perception Simulation 7: Intelligent Robot SLAM Autonomous Navigation Simulation	13	24
Comprehensive Navigation Applications and Competition Practice for Intelligent Robots	8: Space Service Robot Navigation Competition Practice 9: Intelligent Robot Comprehensive Training	10	22

According to the principle of virtual-real integration, physical verification is conducted after simulation validation. It is found that not all successfully simulated cases will necessarily succeed when migrated to physical robots; some cases still require debugging based on actual test results. For example, when programming to obtain real-time camera feed, the subscribed topic should be /camera/color/img_raw instead of /camera/img_raw used in Gazebo.

2.3 Environmental Innovation: Dual-Mode Low-Cost Development Environment

To resolve the Windows-ROS conflict, a VMware-based virtual machine image was developed based on Ubuntu 20.04 + ROS1 Noetic, pre-installed with Gazebo, Rviz, OpenCV, SLAM packages (Gmapping, Cartographer, Hector_Slam), YOLOv8, and DeepSeek [8][9].

A USB hard drive based portable system solves low-configuration and VM lag issues. It runs Ubuntu+ROS from a custom image with Timeshift for fast restoration.

2.4 Pedagogical Innovation: AI-Assisted Programming

Reforming the traditional “copying code” model, AI programming tools such as Doubao and DeepSeek are used as teaching assistants. In addition, a custom AI programming debugging assistant tool based on Doubao has been developed. We design a three-stage progressive teaching method: Stage 1 “Understanding” (30% of class time) – the teacher uses AI to explain code logic step by step; Stage 2 “Reading” (40% of class time) – students complete the code framework and use AI for error correction; Stage 3 “Transfer” (30% of class time) – students modify and optimize the existing code to achieve higher-level learning goals. At the same time, AI usage specifications are formulated to guide students in “scenario-based questioning” [10]. Teachers focus on demonstrating how to modify code according to the observed test results. For example, when testing voice-controlled robot movement, AI often generates code like “if cmd == "move"”, which is too strict to achieve the intended functionality. Students are then guided to revise it to “if cmd. find("move") > -1” so that the robot responds correctly.

The relevant robotics competition tasks (such as the “Intelligent Robot” event of the National Vocational College Skills Competition, the service robot projects of the WRC World Robot Contest, etc.) are deconstructed into classroom teaching tasks.

The five - stage progressive teaching model of “learning, practicing, thinking, expanding, and competing” is formed. This model deconstructs relevant robotics competition tasks into classroom teaching tasks, embedding “competition-driven teaching” into daily instruction to stimulate students’ exploratory awareness and practical abilities.

3 Teaching Outcomes

3.1 Evaluation Indicator System

Learning outcomes improved significantly (Fig. 2). Introductory task success rose from ~60% to >90% in three years. Motion control and environment perception improved by 37.4% and 36.3%, respectively. The grade 2023 outperformed 2022 but lagged 2024, confirming the reform’s continuous optimization.

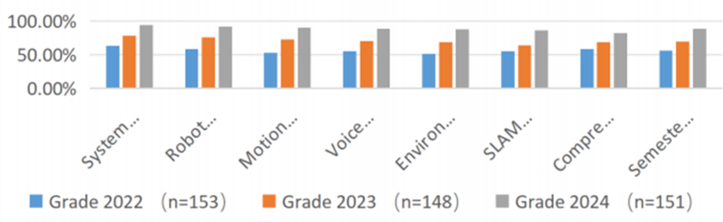

Fig. 2. All stages show a steady upward trend, verifying the continuous optimization value of the reform measures.

The results of the comprehensive assessment and questionnaire survey are presented in Table 2.

Table 2. Results of Comprehensive Assessment and Questionnaire Survey.

Evaluation indicators	Grade 2022 (n=153)	Grade 2023 (n=148)	Grade 2024 (n=151)	2022→ 2024
Comprehensive task completion rate [11]	42.40%	61.40%	84.70%	+42.3%
Proportion of students able to explain their code logic	48.20%	67.10%	88.90%	+40.7%
Proportion of students actively attempting parameter optimization	36.20%	48.60%	73.60%	+37.4%

4 Conclusion

Addressing the challenges in vocational SLAM navigation courses, this study proposes a systematic reform integrating virtual-real simulation and AI empowerment. Three years of practice demonstrate its effectiveness: the development of the first algorithm-oriented digital textbook and a hardware-independent simulation case library; the establishment of a low-cost dual-mode development environment; the innovation of an AI-assisted three-stage pedagogy, which boosted case reproduction success rates from 42% to 89%; and the formation of a five-stage progressive model ("Learn, Practice, Reflect, Expand, Compete"). This scheme offers a replicable and scalable paradigm for vocational robotics education.

Acknowledgments

This paper is supported by the Vocational Education Teaching Reform Project of Shandong Computer Federation titled “Research on Practical Teaching Reform of ‘Robot SLAM Navigation Technology Application’ Based on the Learning-by-Doing Concept”.

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