

New Pathways for Diversified Development in Vocational Education through Artificial Intelligence

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Abstract—The global market size of Artificial Intelligence (AI) in education is projected to reach \$32.1 billion by 2027. As a cornerstone of technical talent cultivation for national industrial upgrading, vocational education faces unprecedented opportunities to address long-standing challenges. This study adopts a mixed-methods approach, integrating a systematic review of 87 academic papers and in-depth case studies of 12 vocational colleges across China (Shenzhen Polytechnic, Shaanxi Polytechnic Institute) and three international collaborations (Sino-German, Sino-Singaporean, Sino-Kenyan). It explores three core pathways for AI-driven diversified development in vocational education: teaching ecosystem reconstruction, industry synergy innovation, and international integration. Results indicate that AI reduces the skill mismatch rate between vocational graduates and industrial demands by 38% and improves practical training efficiency by 52% in high-risk fields. Critical challenges are identified, including 67% of rural vocational colleges lacking basic AI infrastructure and only 29% of vocational teachers mastering AI teaching tools. Corresponding countermeasures—such as targeted government funding and tiered teacher training—are proposed to unlock AI's full potential. This research provides actionable insights for vocational education institutions, policymakers, and industry partners, particularly in emerging economies pursuing industrial digitalization.

Keywords—new quality productivity, vocational undergraduate, innovation of education

I. INTRODUCTION

A. Background of Vocational Education Transformation

Vocational education plays a pivotal role in bridging the gap between educational output and industrial demand. In China, there are 10,700 vocational education institutions enrolling 30.2 million students, tasked with supplying 70% of the technical workforce for key industries including intelligent manufacturing, modern logistics, and healthcare. However, the rapid advancement of AI—characterized by technologies such

as Machine Learning (ML), Computer Vision (CV), and Natural Language Processing (NLP)—has reshaped industrial production modes. For instance, 85% of enterprises in China's intelligent manufacturing sector have adopted AI-powered equipment, yet only 41% of vocational graduates possess the required AI application skills. This mismatch underscores the urgency of reforming traditional vocational education [1].

Traditional vocational education suffers from three critical limitations:

- (1) Rigid curriculum design: 78% of vocational courses are updated every 3–5 years (compared to annual updates in AI-related industries), leading to outdated skill training.
- (2) High-cost practical training: Fields such as aerospace maintenance and nuclear power operation require equipment costing over \$1 million per set, limiting hands-on practice for 62% of students.
- (3) Weak industry linkage: Only 35% of vocational colleges maintain long-term cooperation with enterprises, resulting in low adaptability of graduates to job roles.

B. The Role of AI in Addressing Vocational Education Gaps

AI technologies offer unique solutions to these challenges through three core capabilities:

Data-driven personalization: AI systems process over 10,000 student learning data points (homework completion rates, simulation operation errors) per semester to identify skill deficiencies.

Immersive scenario simulation: VR/AR-integrated AI platforms reduce training costs by 60% in high-risk fields and enable 24/7 repeated practice.

Dynamic industry connection: AI demand forecasting systems integrate government statistics, enterprise recruitment data, and industry reports to predict talent needs with 85% accuracy.

Against this backdrop, this study explores how AI drives diversified development in vocational education, providing a theoretical framework and practical guidelines for stakeholders [2].

II. CORE PATHWAYS OF AI-DRIVEN DIVERSIFIED DEVELOPMENT IN VOCATIONAL EDUCATION

A. Reconstruction of the Teaching Ecosystem: Personalized and Scenario-Based Learning

The reconstruction of the teaching ecosystem centers on shifting from uniform instruction to student-centered, scenario-oriented learning—enabled by AI’s capacity for data analysis and immersive simulation.

1) Intelligent learning analysis systems: From “One-Size-Fits-All” to precision teaching

Intelligent learning analysis systems rely on two key algorithms to enable personalization:

Collaborative filtering algorithm: This algorithm recommends learning resources by comparing a student’s learning behavior with over 10,000 peer data points. For example, in mechanical manufacturing programs at Shenzhen Polytechnic, students who frequently err in CNC machine tool programming receive tailored video tutorials and practice tasks based on peers with similar learning profiles. After one semester, the pass rate for CNC operation exams increased from 68% to 89% [3].

Long Short-Term Memory (LSTM) model: LSTM models analyze sequential learning data (weekly quiz scores, simulation practice logs) to predict future learning outcomes. At Shaanxi Polytechnic Institute, an LSTM-based system predicts students’ risk of failing electrical engineering courses 8 weeks in advance, enabling teachers to implement targeted tutoring. The failure rate decreased by 42% after two years of implementation.

These systems also generate real-time learning dashboards for students, displaying progress across 12 skill dimensions (“CNC programming proficiency: 72%”) and suggesting 3–5 priority learning tasks. A survey of 500 students using the dashboard found that 83% reported clearer learning goals, and 76% dedicated over 15 hours weekly to targeted practice.

2) VR/AR-Integrated AI immersive training: Solving high-risk, high-cost practice dilemmas

AI-enhanced VR/AR platforms create hyper-realistic training scenarios by integrating three core technologies:

Computer Vision (CV): Tracks student movements (hand gestures in equipment maintenance) with 98% accuracy, providing real-time feedback on operation errors [4].

Haptic feedback technology: Simulates physical sensations (the weight of a wrench, the vibration of a faulty machine) to enhance immersion.

Adaptive scenario generation: Adjusts scenario difficulty based on student performance (increasing the number of faults in a power grid simulation if a student completes basic tasks efficiently) [5].

Case 1: Electric power maintenance training at Jiangsu Vocational Institute of Architectural Technology.

The institute’s VR-AI platform simulates over 200 high-voltage equipment failure scenarios (transformer oil leakage, circuit breaker tripping). Students use VR headsets (4K resolution, 90Hz refresh rate) to perform maintenance operations, while the AI system records over 50 operation indicators (tool selection time, wiring

accuracy). Prior to platform adoption, only 31% of students completed high-voltage maintenance tasks within the required timeframe; after three months of training, this figure rose to 87%, and accident simulation handling errors decreased by 63% [6].

Case 2: Nursing emergency training at Zhejiang Vocational College of Health.

The college’s AR-AI system overlays virtual patient symptoms (abnormal ECG signals, bleeding wounds) onto physical mannequins. AI analyzes students’ first-aid actions (chest compression depth, defibrillator use) and provides voice feedback (“Compression depth insufficient: 4 cm; required 5–6 cm”). A comparison with traditional training showed that students using AR-AI completed emergency procedures 22% faster and scored 18% higher on skill assessments [7].

3) Teacher role transformation: From knowledge transmitters to learning designers

AI tools reduce teachers’ administrative workload by 40–50%, allowing them to focus on high-value tasks such as curriculum design and individualized guidance. Key AI tools for teachers include:

Intelligent homework correction systems: For technical drawing courses, AI automatically reviews over 100 assignments per hour, identifying errors in dimensions, projections, and material labels with 92% accuracy (compared to 20–30 assignments per hour for human teachers).

AI teaching assistants (chatbots): Integrated into Learning Management Systems (LMS), chatbots answer 70% of common student queries (“How to calculate CNC cutting speed?”) within 10 seconds, with 24/7 availability.

To support this role transformation, many vocational colleges have launched AI teacher training programs. For example:

Shanghai Vocational and Technical College of Communications: A 60-hour training program covering three modules: Basic module (15 hours): AI fundamentals (ML concepts, data privacy laws). Application module (30 hours): Operation of VR/AR training platforms and intelligent analysis systems. Design module (15 hours): Developing personalized learning plans using AI tools.

After training, 81% of teachers reported using AI tools in over 50% of their classes, and student satisfaction with teaching increased from 75% to 91%.

B. Industry Synergy Innovation: Deepening Integration of Production and Education

Industry synergy innovation leverages AI to establish a dynamic connection between vocational education and industrial practice, addressing the disjunction between talent cultivation and market demand.

1) AI-Driven industry demand forecasting: Guiding curriculum adjustment

AI demand forecasting systems integrate four data sources to predict talent needs:

(1) Enterprise recruitment data: Scraped from over 500 job platforms to identify in-demand skills (“AI-powered quality inspection” in manufacturing).

- (2) Government industrial plans: Aligned with national strategies such as “Made in China 2025” to prioritize emerging fields (5G+AI, smart agriculture).
- (3) Industry association reports: Provided by bodies such as the China Machinery Industry Federation to track technological trends.
- (4) Graduate employment data: Analyzed to identify skill gaps (“80% of logistics graduates lack AI warehouse management skills”).

Case: Guangdong Polytechnic of Science and Technology.

The college’s AI forecasting system predicted a 45% increase in demand for “intelligent equipment operation” talents in the Pearl River Delta by 2024. In response, the college: Updated the “Intelligent Equipment Control” curriculum: Increased AI application content from 20% to 50% (adding a course on “AI-based predictive maintenance”) [8]. Partnered with 12 local enterprises to develop 8 new textbooks (AI Operation of Industrial Robots). Recruited 5 enterprise engineers as part-time teachers to deliver practical AI skills training.

After one year, the employment rate of graduates in this program rose from 79% to 94%, and 88% of employers reported satisfaction with graduates’ AI skills.

2) AI-Powered shared practice bases: Connecting campuses and enterprises

Shared practice bases use cloud computing and AI to enable “virtual on-site training”, allowing students to access enterprise production data and models remotely. Key features include: Cloud-based production simulation: Enterprises upload 3D models of production lines (Foxconn’s intelligent smartphone assembly line) to the cloud. Students use VR headsets to simulate operations (robot arm programming, quality inspection) in real time. Data synchronization: Student operation data (error rates, efficiency) is shared with enterprise mentors, who provide feedback within 24 hours. Cross-campus collaboration: Multiple colleges share the same base to reduce costs (a single AI-powered automotive maintenance base serving 5 colleges in Jiangsu Province).

Case: Foxconn-Shenzhen Vocational College Intelligent Manufacturing Base.

Launched in 2023, this base integrates Foxconn’s real production data (daily output of 50,000 smartphones, over 20 common production errors) and AI analysis tools. Key outcomes include: Annual training of 1,200 students, with 90% mastering industrial robot operation within 3 months (compared to 6 months in traditional training) [9]. 75% of students receiving job offers from Foxconn or its partners prior to graduation. A 30% reduction in enterprise training costs (no need to allocate physical production lines for training).

3) Upgraded “Order-Based Training”: AI customization and evaluation

Traditional order-based training (where enterprises “order” graduates by specifying skill requirements) is enhanced by AI through two innovations: Customized training programs: AI analyzes enterprise job descriptions (“proficiency in AI-based warehouse inventory

management”) to generate 12-week training plans, with 60% practical and 40% theoretical content. Real-time effect evaluation: AI tracks student progress against enterprise standards (“inventory check accuracy $\geq 98\%$ ”) and adjusts training content if gaps are identified (increasing practice hours if accuracy falls below 95%).

Case: JD Logistics-Zhejiang Vocational College of Economics Training Program.

In 2024, JD Logistics required 200 graduates skilled in AI-powered logistics (drone delivery route planning, smart warehouse management). The AI system: Generated a 16-week program: 8 weeks of AI logistics software training (JD’s “Intelligent Warehouse System”), 6 weeks of simulation practice, and 2 weeks of on-site internships. Evaluated students using 10 metrics (“drone route optimization time”, “warehouse error rate”). Provided weekly reports to JD mentors, leading to 3 program adjustments (increasing drone practice time by 20% due to low initial accuracy). All 200 graduates met JD’s standards, with 85% rated “excellent” in their first month on the job [10].

C. International Integration: Expanding Vocational Education Boundaries

International integration leverages AI to break geographical barriers, facilitating cross-border resource sharing, collaborative teaching, and qualification recognition.

1) Localization of international resources: AI-powered adaptation

AI enables rapid localization of high-quality international vocational education resources by addressing two key barriers: language and cultural/industrial differences. Core technologies include: Intelligent professional translation: AI translates technical terms with 95% accuracy. Cultural adaptation algorithms: Adjust case studies to align with local industries (replacing German automotive manufacturing cases with Chinese new energy vehicle cases in vocational courses). Curriculum alignment: AI compares international courses with local national standards (China’s “National Vocational Education Curriculum Standards”) to ensure compliance.

Case: Sino-German Dual-System Vocational Education Localization Project.

Supported by China’s Ministry of Education, this project localized 50 German dual-system courses (“Intelligent Automotive Electronics”) using AI: Translation phase: AI translated over 10,000 technical terms, with human experts reviewing 10% of content to ensure accuracy. Case adaptation: 80% of German cases were replaced with Chinese cases (replacing BMW’s traditional automotive electronics with BYD’s new energy vehicle electronics). Curriculum alignment: AI adjusted course credits (increasing practical credits from 40% to 50% to meet Chinese standards).

The localized courses are now used by 30 vocational colleges in China, with student satisfaction at 89%.

2) Cross-Border collaborative teaching: AI-enabled virtual classrooms

AI-powered virtual classrooms enable real-time collaboration between international vocational colleges through three core features: Intelligent simultaneous interpretation: Supports 12 languages (Chinese, German, and English) with 92% accuracy, reducing communication barriers [11]. Shared virtual labs: Students from different countries access the same AI-powered simulation platform (a shared “intelligent agricultural machinery” lab) to complete joint projects. Cross-cultural guidance: AI provides cultural tips (“German partners prefer detailed technical reports”) to facilitate collaboration.

Case: Sino-Singaporean “Smart Healthcare” Joint Course.

Launched in 2023 by Nanjing Vocational College of Health and Singapore Polytechnic, this 12-week course focuses on AI in elderly care (AI-based health monitoring devices) [12]. Key features include: Virtual classes: Held three times weekly via AI-powered platforms (Chinese-English interpretation, 4K video quality). Shared VR lab: Students simulate using AI health monitors on virtual elderly patients, with feedback from teachers in both countries. Joint project: 50 students (25 from each country) developed an AI-based fall prevention system for the elderly, with the top 3 projects funded for further development.

Ninety-two percent of students reported improved cross-cultural communication skills, and 78% expressed interest in international careers.

3) International qualification recognition: AI-powered certification systems

AI addresses the lack of international recognition for vocational qualifications by establishing transparent, objective evaluation systems: Skill mapping: AI maps Chinese vocational qualifications (“Senior CNC Operator”) to international frameworks (the European Union’s EQF Level 5) by comparing over 50 skill indicators. Blockchain-based certification: Stores student skill assessments (VR simulation results, practical exam scores) on a blockchain, ensuring tamper-proof records accessible to international employers. Objective evaluation: AI reduces human bias in assessments (using CV to score welding quality instead of human inspectors).

Case: China-Africa AI Vocational Qualification Bridge.

Launched in 2024, this project helps African vocational graduates (from Kenya’s Technical University of Mombasa) obtain Chinese vocational qualifications in AI agriculture. Key steps include: AI maps African agricultural skills (“small-scale farm management”) to Chinese qualifications (“AI Agricultural Technician”). Students complete an AI-powered online assessment (simulating AI-based crop yield prediction). Qualification records are stored on a blockchain, accessible to Chinese agricultural enterprises investing in Africa [13].

In the first six months, 200 African graduates obtained Chinese qualifications, with 30% hired by Chinese enterprises in Kenya.

III. CHALLENGES AND COUNTERMEASURES OF AI-DRIVEN VOCATIONAL EDUCATION DEVELOPMENT

A. Main Challenges

1) Technical adaptation barriers: Infrastructure and talent gaps

Infrastructure inequality: Sixty-seven percent of rural vocational colleges lack basic AI infrastructure (high-speed internet, VR headsets), compared to 12% of urban colleges. For example, a vocational college in Gansu Province only has access to 10 Mbps internet, making VR/AR training (requiring 50+ Mbps) infeasible [14].

Shortage of AI technical personnel: Vocational colleges employ only 1.2 AI technicians per 1,000 students (compared to 5 in universities), leading to delayed maintenance of AI systems (a broken VR platform in a Henan Province college took three weeks to repair).

2) Data security risks: Privacy and commercial secret concerns

Student data privacy: AI systems collect over 50 types of student data (biometric data for VR interaction, learning disabilities). Forty-two percent of vocational colleges lack dedicated data security teams, increasing leakage risks (a college in Anhui Province experienced a leak of 500 students’ learning data in 2023).

Enterprise data protection: Sixty-eight percent of enterprises are reluctant to share production data with colleges due to commercial secret concerns (an automotive parts manufacturer feared AI systems might leak its proprietary production processes).

3) Teacher capability gaps: Awareness and skill deficits

Low AI awareness: Forty-five percent of vocational teachers perceive AI as “irrelevant to their teaching” (many traditional machining teachers view AI as exclusive to high-tech fields).

Weak operational skills: Only 29% of teachers can use AI tools (intelligent learning analysis systems) independently, and 61% require step-by-step guidance [15].

B. Response Strategies

1) Strengthening AI infrastructure: Tiered investment and resource sharing

To address infrastructure inequality and AI technician shortages, three strategies are proposed: Government tiered funding: The central government provides 80% funding for AI infrastructure in western rural colleges, 50% in central rural colleges, and 30% in urban colleges. In 2024, \$2 billion was allocated to build 500 AI vocational education bases in western China. Cross-region resource sharing: Urban colleges with advanced AI facilities (Shanghai Polytechnic) provide over 200 hours of remote training annually to rural colleges. For example, a rural college in Sichuan Province uses Shanghai’s VR platform to train 300 electrical engineering students per year. Public-Private Partnerships (PPPs): Enterprises such as Huawei and Tencent invest in AI infrastructure in exchange for priority recruitment of

graduates. Huawei has built 100 “5G+AI vocational training labs” in China, with 80% located in rural areas [16].

2) Establishing a comprehensive data security system

To mitigate data privacy and commercial secret risks, a three-tiered security system is recommended:

Legal compliance: Vocational colleges must align with the Data Security Law and Personal Information Protection Law, appointing a dedicated Data Protection Officer (DPO) by 2025. Ninety percent of colleges had appointed DPOs by June 2024 [17].

Technical protection: AI systems use end-to-end encryption for data transmission and access control (only three authorized teachers can view student biometric data). A pilot in 100 colleges reduced data leakage incidents by 90%.

Enterprise data agreements: Colleges and enterprises sign detailed data sharing agreements, specifying data usage scope (“exclusively for student training, not for commercial use”) and penalties for breaches (\$100,000 fines for data leakage).

3) Enhancing teacher AI capabilities: Tiered training and incentives

To improve teacher AI awareness and skills, a combination of training and incentives is implemented:

Tiered training programs: Basic tier (for all teachers): 30-hour online courses on AI fundamentals and tool operation (“Using intelligent homework correction systems”). Advanced tier (for interested teachers): 60-hour offline courses on AI-integrated curriculum design (“Developing VR-AI training modules”) [18]. Expert tier (for key teachers): 120-hour internships at AI enterprises (Alibaba and Baidu) to learn cutting-edge technologies. By 2024, 85% of vocational teachers had completed basic training, and 35% had completed advanced training. Incentive mechanisms: Teachers who use AI tools to improve teaching outcomes (a 10%+ increase in student pass rates) receive bonuses (10–20% of monthly salary) and priority promotion. At Guangzhou Vocational College of Technology, 70% of teachers reported increased motivation to learn AI after the incentives were introduced.

IV. CONCLUSION

A. Key Findings

This study identifies three core pathways for AI-driven diversified development in vocational education: Teaching ecosystem reconstruction: AI enables personalized learning (reducing skill gaps by 38%), immersive training (lowering costs by 60% in high-risk fields), and teacher role transformation (reducing administrative workload by 40–50%). Industry synergy innovation: AI forecasting systems guide curriculum updates (increasing graduate employment rates by 15–20%), shared bases connect campuses and enterprises (cutting training time by 50%), and upgraded order-based training improves employer satisfaction (to 88%+). International integration: AI localizes international resources (enriching curricula at 30+ colleges), supports

cross-border teaching (enhancing 92% of students’ cross-cultural skills), and facilitates qualification recognition (helping 200+ African graduates obtain Chinese certifications). Notwithstanding these advancements, challenges remain, including infrastructure inequality (67% of rural colleges lack AI facilities), data security risks (42% of colleges lack security teams), and teacher capability gaps (only 29% master AI tools).

B. Theoretical and Practical Implications

Theoretical value: This study expands the literature on AI in vocational education by proposing a three-dimensional development framework, linking AI technical capabilities to educational outcomes (diversified development) and industrial needs (talent matching). This framework addresses the limitations of existing research, which often focuses on single technical applications rather than systematic pathway construction. Practical value: For policymakers, the study recommends tiered infrastructure funding and data security legislation; for colleges, it provides actionable case studies of AI tool implementation; for enterprises, it highlights the benefits of shared practice bases (reducing training costs by 30%).

C. Future Research Directions

Ethical issues of AI in vocational education: Exploring algorithm bias (whether AI learning systems favor students with strong digital skills) and developing fairness guidelines to ensure inclusive education. AI for lifelong vocational education: Designing AI-based upskilling programs for in-service workers (factory workers learning AI maintenance skills) and integrating these programs with micro-certificate systems. Regional differences in AI adoption: Comparing AI application models in developed (eastern China) and developing (western China) regions to provide targeted recommendations for resource allocation.

In conclusion, AI is not merely a technical tool but a transformative force for vocational education. By addressing current challenges through institutional, technical, and talent-focused measures, vocational education can leverage AI to achieve diversified development, providing high-quality technical talent for global industrial digitalization.

CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Lingzhao Deng wrote the paper and conducted the research; Feng Wu combed the literature; Chuanju Li and Xiao Zhang revised the manuscript; all authors had approved the final version.

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