Curriculum and Teaching Methodology (2026)
Clausius Scientific Press, Canada
DOI: 10.23977/curtm.2026.090123
ISSN 2616-2261 Vol. 9 Num. 1

Analysis of Teaching Reform in Vocational Mechanical Engineering Programs in the Context of Smart Manufacturing

Yanhui Chen*

Guangdong Meizhou Vocational and Technical College, Guangdong, Meizhou, 514011, China
**Corresponding author: Chenyanhui@gdmzvtc.edu.cn*

Keywords: Intelligent Manufacturing; Higher Vocational Education; Mechanical Engineering Programs; Teaching Reform; Industry-Education Integration

Abstract: The rapid advancement of intelligent manufacturing technologies has imposed new demands on the cultivation of mechanical engineering professionals in higher vocational education. This paper analyzes issues in the current teaching practices of vocational mechanical engineering programs, including fragmented curriculum systems, outdated teaching methods, lagging practical training platforms, insufficient faculty capabilities, and shallow industry-academia collaboration. It proposes reform pathways such as restructuring curriculum systems, innovating teaching methods, upgrading practical training platforms, building dual-qualified faculty teams, and improving industry-academia cooperation mechanisms. These reforms aim to cultivate high-quality technical and skilled talents adaptable to smart manufacturing development and enhance the program's capacity to serve industrial upgrading.

1. Introduction

As a product of the deep integration of next-generation information technology and advanced manufacturing technology, smart manufacturing is driving a global transformation in the manufacturing sector. China's accelerated digital transformation in manufacturing, coupled with the increasing adoption of smart manufacturing equipment and systems, has introduced new demands on the competency structure of technical and skilled personnel. As a vital training ground for frontline technical professionals in intelligent manufacturing, higher vocational mechanical engineering programs face an urgent need for pedagogical reform. This paper analyzes shifts in talent demand within the intelligent manufacturing landscape, examines current teaching practices and challenges, and proposes a systematic reform pathway. The goal is to optimize talent cultivation models and enhance program adaptability.

2. New Requirements for Mechanical Engineering Programs in Higher Vocational Education amid Smart Manufacturing Development

2.1 Current Status and Trends in Smart Manufacturing Technology

Smart manufacturing technology is currently undergoing rapid advancement, characterized by the deep integration of digital twins, industrial internet, and artificial intelligence with traditional manufacturing. The intelligence level of mechanical equipment continues to rise, with CNC machine tools integrating sensor networks, real-time monitoring, and fault diagnosis systems now widely deployed. Remote control technology based on 5G communication has eliminated spatial constraints in equipment operation and maintenance. Intelligent robots are progressively replacing manual labor in precision machining and complex assembly operations; additive manufacturing technologies enable the one-step production of intricate components. Future intelligent manufacturing will evolve toward comprehensive sensing, autonomous decision-making, and adaptive production[1]. Flexible production lines and unmanned workshops will become industry standards, while human-machine collaborative intelligent systems will reshape traditional manufacturing models. These technological transformations are fundamentally redefining the knowledge structure and competency requirements for mechanical engineering professionals.

2.2 Shifting Skill Requirements in the Mechanical Industry under Smart Manufacturing

The mechanical industry's skill demands are undergoing structural transformation under smart manufacturing. The emphasis on traditional process design and equipment operation skills is declining, while the need for digital design, smart equipment maintenance, and system integration capabilities is surging significantly. Mechanical design now requires engineers to master parametric design and simulation optimization. During manufacturing, CNC programming extends beyond single-machine operation to encompass multi-axis coordination and complex surface machining. Equipment maintenance has expanded from mechanical troubleshooting to sensor system diagnostics and network communication debugging[2]. Automated production lines require understanding PLC control logic and performing basic program adjustments. Data analysis capabilities have become a key factor in boosting production efficiency. Interdisciplinary collaboration and communication have emerged as essential skills for manufacturing engineers. These shifts are directly challenging the traditional talent development models of mechanical engineering programs.

2.3 Adjustment Directions for Vocational Mechanical Engineering Talent Development Goals

The talent development goals for vocational mechanical engineering programs must shift from training single-skill technical operators to cultivating versatile smart manufacturing technology application professionals. The focus should be on developing applied talent for intelligent equipment who possess both mechatronics knowledge and practical capabilities. The new training direction should strengthen students' holistic understanding of intelligent manufacturing system architecture. Building upon mechanical design and CNC machining skills, it should integrate core competencies such as industrial robot programming and application, intelligent sensing and detection, and industrial communication network configuration. Emphasis should be placed on developing students' abilities to install, debug, maintain, and diagnose faults in intelligent manufacturing equipment within real production environments[3]. Vocational colleges should strengthen training in data collection and analysis to enable students to interpret production process data and make basic optimization decisions. Simultaneously, instructors should emphasize sustainable learning capabilities and comprehensive problem-solving skills to adapt to the rapid technological iteration and industrial upgrading demands of smart manufacturing.

3. Analysis of Current Teaching Practices and Challenges in Higher Vocational Mechanical Engineering Programs

3.1 Disconnect Between Traditional Curriculum and Smart Manufacturing Demands

The current curriculum framework for mechanical engineering programs in higher vocational education remains centered on traditional disciplines such as mechanical manufacturing processes, mechanical design, and hydraulics and pneumatics. Courses on emerging technologies like digital design and intelligent control account for a disproportionately low share. Within core mechanical engineering courses, CNC machining technology instruction remains confined to basic programming, lacking content on advanced CNC system applications. CAD/CAM courses emphasize 2D drafting rather than 3D parametric design and simulation verification; Mechanical principles and component design fail to incorporate lightweight design concepts; PLC and automation control courses remain disconnected from industrial robotics and industrial internet technologies; Professional electives virtually lack key smart manufacturing technologies like big data analytics and artificial intelligence applications[4]. This lag in curriculum updates disconnects students' knowledge from real-world applications, making them ill-equipped for smart manufacturing roles.

3.2 Discrepancies between Teaching Methods and Actual Demands of Intelligent Manufacturing

Teaching methods in vocational mechanical engineering programs predominantly rely on traditional knowledge-based lectures, lacking simulation and reproduction of real-world workflows in smart manufacturing environments. Theoretical courses underutilize interactive technologies like virtual simulation and augmented reality, making it difficult to visually demonstrate the complex internal structures of intelligent equipment. CNC programming courses remain confined to code explanation, lacking advanced applications like multi-axis coordination and complex surface machining for smart manufacturing. Mechatronics courses fragmentarily cover mechanical, electrical, and control knowledge, failing to cultivate systematic integration thinking. Project-based teaching relies on outdated case studies that do not reflect smart factory production scenarios[5]. Course evaluations still prioritize theoretical assessments, inadequately measuring students' problem-solving abilities in operating and maintaining complex intelligent equipment. These teaching methods struggle to develop students' practical skills for adapting to intelligent production environments.

3.3 Practical Teaching Environments Lag Behind Smart Manufacturing Technology Development

The development of practical teaching platforms for mechanical engineering programs at higher vocational colleges lags significantly behind advancements in intelligent manufacturing technology, with traditional machining training equipment still dominating. Basic training labs feature outdated CNC machine models, lacking five-axis machining centers, intelligent CNC systems, and online inspection capabilities. Industrial robot training equipment is limited in quantity and predominantly consists of educational robots, lacking industrial-grade equipment. Training facilities for intelligent manufacturing system integration are insufficient, failing to simulate the operational processes of smart production lines. Virtual simulation training systems have limited coverage, making it difficult to support large-scale simultaneous training for students in intelligent equipment operation and fault diagnosis[6]. On-campus production-oriented training bases are disconnected from real industrial environments, unable to reflect the IoT architecture of smart factories. This lag in practical teaching environments constrains the development of students' applied skills in intelligent manufacturing technologies.

3.4 Insufficient Knowledge Structure and Capabilities in Smart Manufacturing among Faculty

The knowledge structure and capabilities of vocational mechanical engineering faculty in smart manufacturing exhibit significant shortcomings, rendering them ill-equipped to fulfill teaching responsibilities within the smart manufacturing context. Most instructors graduated from traditional mechanical engineering programs, lacking sufficient understanding of core smart manufacturing technologies such as industrial robot programming, machine vision, and industrial IoT. Additionally, their limited industrial experience leaves them deficient in practical smart factory operations[7]. The aging faculty faces learning bottlenecks when adopting new technologies, struggling to rapidly master smart manufacturing software platforms. Cross-disciplinary teaching capabilities are inadequate, hindering effective integration of knowledge from mechanical, electrical, information, and artificial intelligence fields. The lag in knowledge renewal and competency enhancement among instructors results in outdated teaching content and obsolete pedagogical methods.

3.5 Inadequate School-Enterprise Collaborative Training Mechanisms

The school-enterprise collaborative training mechanism for vocational mechanical engineering programs suffers from superficiality, shallow engagement, and low efficiency, hindering the formation of a cohesive force for cultivating smart manufacturing talent. Cooperation often remains limited to providing internship positions and hiring graduates, with insufficient depth in corporate involvement throughout the entire talent development process. Off-campus training bases lack sustainable investment mechanisms, and enterprises show limited willingness to share smart manufacturing resources. Corporate experts have low involvement in developing talent cultivation plans, resulting in mismatches between training objectives and job requirements. Course development lacks systematic analysis of enterprise smart manufacturing workflows[8]. Faculty practical training at enterprises often becomes a formality, failing to enable genuine engagement with smart manufacturing technology applications. These imperfections in the collaborative training mechanism create structural conflicts between talent cultivation and industrial demands.

4. Innovation Pathways for Teaching Reform in Vocational Mechanical Engineering Programs under Smart Manufacturing

4.1 Reconstructing the Curriculum System to Meet Smart Manufacturing Technology Demands

The restructuring of vocational mechanical engineering curricula should center on the intelligent manufacturing technology chain and industrial chain, establishing a “platform + module” course structure. Fundamental mechanical platform courses must integrate digital design concepts, upgrading traditional mechanical drafting to parametric design and simulation optimization. Core professional courses should increase the emphasis on mechatronics technology and intelligent control systems, while expanding CNC technology courses to cover multi-axis coordination and complex surface machining techniques. Higher vocational institutions should introduce specialized modules in intelligent manufacturing, including industrial robotics applications and programming, intelligent sensing and detection technologies, and industrial IoT applications. Curriculum designers should integrate mechanical manufacturing processes with intelligent production line planning and digital twin technology applications. Academic departments should expand elective offerings to include cutting-edge courses such as big data analytics and artificial intelligence applications[9]. The new curriculum framework should transcend disciplinary boundaries, emphasize interdisciplinary integration, and establish a systematic knowledge architecture that cultivates practical capabilities in intelligent manufacturing technology applications.

4.2 Innovative Teaching Methods Aligned with Smart Manufacturing Workflows

Innovative teaching methods should be guided by real-world intelligent manufacturing workflows, adopting project-driven and blended learning approaches. Instructors should develop project-based teaching resources centered on typical tasks such as design, manufacturing, assembly, debugging, and operation/maintenance of intelligent manufacturing equipment. Educational institutions should utilize virtual simulation technology to construct digital teaching environments for intelligent manufacturing, enabling students to immerse themselves in the working principles of intelligent equipment through virtual assembly and debugging. Teachers should employ problem-based learning approaches to design authentic scenarios like fault diagnosis and troubleshooting on smart production lines, cultivating students' comprehensive analytical and problem-solving abilities[10]. Program administrators should implement a blended learning model integrating "online learning + offline practice," combining video tutorials, interactive operations, and online assessments. Teaching departments should reform assessment methods to prioritize evaluating students' technical application skills and innovative thinking in smart equipment operation and maintenance.

4.3 Upgrading Practical Teaching Platforms to Strengthen Smart Manufacturing Application Capabilities

The upgrade of practical teaching platforms should be grounded in industry-education integration to create a multi-tiered smart manufacturing training environment. Vocational colleges should establish a smart manufacturing training center based on the industrial internet architecture, equipped with industrial-grade intelligent CNC machinery, multi-joint industrial robots, intelligent logistics systems, machine vision devices, and other equipment to construct a comprehensive smart production line training system. Educational institutions should develop a digital training platform integrating virtual and physical elements, enabling data interaction between physical equipment and virtual models through digital twin technology, allowing students to program smart equipment and debug systems in a virtual environment. Higher vocational schools should establish an Intelligent Manufacturing Technology Application Innovation Laboratory equipped with additive manufacturing equipment, edge computing devices, and industrial big data analytics platforms to support student innovation practices in intelligent manufacturing technologies. Training departments should enhance the Comprehensive Intelligent Manufacturing Training Center by setting up workstations for job clusters such as intelligent equipment installation/debugging and production line operation/maintenance. Educational administrators should collaborate with leading enterprises to build smart factory training bases, integrating authentic industrial production environments and technical standards.

4.4 Building a Dual-Qualified Faculty to Enhance Smart Manufacturing Instruction

Building a dual-qualified faculty requires diversified training pathways to enhance teachers' capabilities in teaching intelligent manufacturing. Higher vocational institutions should implement a

"Digital Teacher" training program, organizing faculty to participate in specialized training on industrial robot programming, intelligent sensing technology, and industrial internet to systematically improve their application skills in intelligent manufacturing technologies. Educational administrators should establish a school-enterprise faculty exchange mechanism, arranging professional instructors to undertake technical practice at intelligent manufacturing enterprises for six months or longer, participating in corporate intelligent transformation projects to accumulate practical experience. Human resource departments should recruit engineers and technical experts from the intelligent manufacturing sector as adjunct faculty to form interdisciplinary teaching teams, fostering collaborative teaching across mechanical, electrical, information, and artificial intelligence domains. Academic leaders should establish research teams focused on intelligent manufacturing technologies, encouraging faculty participation in corporate R&D and application projects. School administration should refine teacher evaluation and incentive mechanisms by incorporating proficiency in intelligent manufacturing technologies, teaching innovation achievements, and industry-education integration projects into assessment frameworks.

4.5 Refining the School-Enterprise Collaboration Mechanism to Establish a New Model for Intelligent Manufacturing Talent Development

Innovation in school-enterprise cooperation mechanisms should focus on deep integration between industry and education, building a multi-party collaborative ecosystem for cultivating smart manufacturing talent. Vocational education administrators should establish a professional development steering committee jointly participated by vocational colleges, leading smart manufacturing enterprises, and industry associations, deeply involved in formulating talent development plans and evaluating teaching quality. Program coordinators should implement order-based training and modern apprenticeship programs, with schools and enterprises jointly designing training plans to precisely cultivate smart manufacturing technical application talent according to corporate job requirements. Educational institutions should implement the "work-study rotation" training model, integrating real-world enterprise smart manufacturing projects into the teaching process, with students alternating between on-campus and off-campus learning and practice. Vocational colleges and industry partners should establish a "dual-track" education mechanism where enterprise technical experts serve as part-time mentors throughout the teaching process. Educational institutions and enterprises should jointly build smart manufacturing technology innovation centers for collaborative technical breakthroughs and applied research. Stakeholders in education and industry should construct a talent co-development and sharing mechanism to achieve complementary resources and mutually beneficial development.

5. Conclusion

Teaching reform in vocational mechanical engineering programs under the context of intelligent manufacturing is an inevitable choice to adapt to industrial upgrading and technological transformation. Through systematic reform measures such as restructuring the curriculum system, innovating teaching methods, upgrading practical platforms, building a dual-qualified faculty, and enhancing industry-academia collaboration, prominent issues in current teaching can be effectively addressed. This approach cultivates high-quality technical and skilled talents who meet the demands of intelligent manufacturing development. Future teaching reforms should further strengthen digital transformation and deepen industry-education integration to continuously improve talent cultivation quality and the program's capacity to serve the industry.

References

[1] Yang F .Study on Teaching Mode Innovation of Higher Vocational Education Under the Background of "Internet Plus"[J].International Journal of Cognitive Informatics and Natural Intelligence, 2025, 19(1):1-16.

[2] Wang J .Research on the Integration Teaching Model of Computer English in Higher Vocational Education under the Background of Post-Work-Competition-Certificate[J].Journal of Higher Education Research, 2025, 6(1):53.

[3] Huang X .Research on Project-based Teaching Reform of Nautical English in Higher Vocational Colleges under the Background of Informatization[J]. Applied Mathematics and Nonlinear Sciences, 2024, 9(1).

[4] Wang S , Hu X , Yuan M ,et al. Analysis of the Teaching Reform Path for Environmental Engineering Technology Majors in Higher Vocational Education Based on the "1+X" Certificate[J].Education Reform and Development, 2024, 6(9):50-61.

[5] Chen X , Duan C , Hu Z .Innovative Practice and Teaching Reform Strategies of Artificial Intelligence Technology in the Teaching of Higher Vocational Food Testing[J].Applied Mathematics and Nonlinear Sciences, 2024, 9(1).

[6] Shijie Z , Qian L .Innovative Strategies for Teaching Models in Higher Vocational English Education under the Background of Artificial Intelligence[J].Journal of Higher Vocational Education, 2024, 1(3):308-315.

[7] Yue X .Exploration of Precision Teaching Reform of Ceramics Education in Higher Vocational School under the Background of Big Data Technology[J].Applied Mathematics and Nonlinear Sciences, 2024, 9(1).

[8] Zhao T. Curriculum Reform of Higher Vocational Mathematics Under the Background of Digital Transformation [J].Journal of Contemporary Educational Research, 2024, 8(4):215-220.

[9] Lin J .Research on the Teaching Mode of Business German Course in Higher Vocational Colleges Under the Background of "Internet Plus"[J].The Educational Review, USA, 2024, 8(1):113-117.

[10] Deng L , Pei X .Research on the Teaching Reform of Cross-Border E-Commerce Courses in Higher Vocational Universities under the Background of the Digital Era[J].International Journal of Learning and Teaching, 2023, 9(4).