Research on the Collaborative Development Path of AI Teaching and Industry-Education Integration of Intelligent Manufacturing Specialty Groups in Higher Vocational Colleges

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***Abstract*：** *With the in-depth advancement of the new round of technological revolution and industrial transformation, the intelligent manufacturing industry is accelerating its digital and intelligent transformation, leading to a growing market demand for high-quality compound technical and skilled talents with practical capabilities. The full-scale empowerment of artificial intelligence (AI) technology has restructured the talent training logic of higher vocational education and promoted the iterative upgrading of traditional teaching paradigms. As the core carrier for higher vocational colleges to connect with the advanced manufacturing industry, the in-depth collaboration and two-way empowerment between AI teaching reform and industry-education integration are critical to resolving the structural mismatch between talent training and industrial demands and improving education quality. Adopting the research methods of literature review, comparative analysis and case study, this paper systematically sorts out domestic and foreign research findings and practical paradigms, and analyzes the key problems restricting collaborative development, including superficial integration, lagging curriculum system iteration, insufficient compound teachers, and imperfect long-term guarantee mechanisms. By constructing a multi-dimensional comparative model, this paper evaluates the advantages, disadvantages and applicable scenarios of different AI teaching and industry-education integration modes. On this basis, a systematic collaborative development path is constructed from four dimensions including concept reconstruction, system optimization, mechanism innovation and resource guarantee, providing theoretical support and practical references for the connotation construction of intelligent manufacturing specialty groups and the precise docking of industrial talent demands in higher vocational colleges.*

***Keywords*：** *Higher vocational colleges; intelligent manufacturing specialty groups; AI teaching; industry-education integration; collaborative development*

1. Introduction

1.1 Research Background

The global manufacturing pattern is undergoing profound restructuring, and the industrial intelligent transformation has entered a crucial stage. With the continuous implementation of China's strategy of building a strong manufacturing country, policy documents such as the Implementation Opinions on the Special Action of Artificial Intelligence + Manufacturing have clarified the development orientation of in-depth integration between artificial intelligence and the real economy. Such policies have reshaped the post standards and talent specifications of the intelligent manufacturing industry, putting forward compound training requirements for vocational education, namely proficient manufacturing process cognition, skilled AI application, and comprehensive practical capabilities. Covering core majors such as industrial robot technology, mechatronic integration technology and numerical control technology, the intelligent manufacturing specialty groups in higher vocational colleges precisely connect with key links of the industrial chain including high-end equipment manufacturing and intelligent production operation and maintenance, serving as the core platform for manufacturing talent training.

As the digital transformation of vocational education advances comprehensively, AI technology has been gradually integrated into the whole teaching process of higher vocational education, empowering teaching innovation and high-quality development of industry-education integration. However, most higher vocational colleges still face prominent problems such as superficial AI teaching and fragmented industry-education integration, lacking a sound collaborative education mechanism. The specific manifestations include the disconnection between AI courses and professional skills, the limitation of school-enterprise cooperation to simple internship and employment docking, and the lag of talent training in meeting the demands of emerging posts such as intelligent production line operation and maintenance and industrial data analysis, resulting in a structural mismatch between talent supply and industrial development. Against this background, exploring the in-depth coupling path of AI teaching and industry-education integration is an inevitable choice for higher vocational colleges to break through development bottlenecks and adapt to the intelligent upgrading of the manufacturing industry[1].

1.2 Research Significance

1.2.1 Theoretical Significance

This paper integrates the research achievements of AI teaching reform and industry-education integration innovation, and clarifies the internal coupling logic of collaborative education. It makes up for the research deficiencies in current academic circles, such as emphasizing single-dimensional research and case summary while ignoring two-way collaborative analysis and paradigm comparison. This research further enriches the theoretical system of vocational education digital transformation and the connotation construction of intelligent manufacturing specialty groups, optimizes the theoretical framework for cultivating compound intelligent manufacturing talents, and provides new perspectives and theoretical support for subsequent academic research and professional construction.

1.2.2 Practical Significance

Based on the practical pain points of industrial development and vocational education, this paper summarizes the core cruxes of collaborative development and proposes implementable and replicable development paths. The research findings can provide practical guidance for higher vocational colleges to optimize talent training programs, reconstruct AI-integrated curriculum systems and innovate school-enterprise collaborative mechanisms. Furthermore, it helps colleges cultivate compound talents adapting to industrial intelligent demands, improve students' post adaptability and core competitiveness, promote the precise connection of the education chain and talent chain with the industrial chain and innovation chain, and empower the intelligent upgrading of regional manufacturing industries.

1.3 Research Status at Home and Abroad

1.3.1 Foreign Research Status

Manufacturing powers including Europe, America, Japan and South Korea have formed mature industry-education integration modes for vocational education. Germany has upgraded its classic dual-system education model, integrated cutting-edge technologies such as AI and digital twin into the vocational education system, and built an enterprise-led work-study integration education system focusing on training practical talents for intelligent factories. Community colleges in the United States implement an industry-driven school-enterprise linkage mode, in which industry associations formulate unified teaching standards for AI and intelligent manufacturing, build virtual-real integrated training scenarios, and focus on improving students' capabilities of intelligent scenario application and industrial problem solving. Relying on the advantages of precision manufacturing, Japan promotes in-depth cooperation between vocational colleges and leading enterprises to build AI R&D and training bases for scenario-based technology application. In general, foreign research focuses on the integration of technology and industrial scenarios, but mostly focuses on the summary of single national models, lacking multi-mode comparison and systematic collaborative research oriented to specialty groups[2].

1.3.2 Domestic Research Status

Domestic scholars have carried out extensive research on AI teaching and industry-education integration of intelligent manufacturing specialty groups. In terms of AI teaching reform, most studies advocate constructing a modular curriculum system of "artificial intelligence + specialty", and apply virtual simulation and digital twin technology to practical teaching to solve the limitations of traditional training. In the field of industry-education integration, vocational colleges have explored diversified cooperation modes such as equity empowerment and group-chain coupling, forming a preliminary multi-subject collaborative education framework. Nevertheless, existing research still has obvious shortcomings. Most studies focus on individual cases and partial innovation, lacking horizontal comparison and adaptive evaluation of different education modes. Research on the in-depth collaborative logic and long-term operation mechanism of AI teaching and industry-education integration is insufficient, and the countermeasures for core problems such as benefit distribution and teacher incentive are poorly targeted, resulting in insufficient systematicness and practicability of relevant research.

1.4 Research Contents and Methods

1.4.1 Research Contents

The core research contents of this paper include four parts. Firstly, it defines core concepts and clarifies the theoretical logic of the collaborative development of AI teaching and industry-education integration. Secondly, it summarizes the current achievements of collaborative education and analyzes the key problems and restrictive factors. Thirdly, it compares the characteristics, advantages, disadvantages and applicable scenarios of three types of AI teaching modes and three types of industry-education integration modes. Finally, based on problem orientation, it constructs a practical collaborative development path from the dimensions of concept, system, mechanism and resource[3].

1.4.2 Research Methods

Literature Research Method: This paper systematically sorts out relevant policies, academic papers and research reports on vocational education digitalization, AI-enabled teaching and industry-education integration, consolidates the theoretical foundation of the research, and clarifies the research innovation points.

Comparative Analysis Method: A two-dimensional comparative analysis framework is constructed to compare the adaptive boundaries, advantages and disadvantages of different AI teaching and industry-education integration modes, so as to provide basis for mode selection and path optimization.

Case Analysis Method: Taking benchmark higher vocational colleges including Zhejiang University of Mechatronic Engineering and Chongqing Chuangke Vocational College as research cases, this paper summarizes their innovative practices in collaborative education and refines replicable practical experiences to ensure the practicability of the research conclusions.

2. Core Concepts and Theoretical Basis

2.1 Definition of Core Concepts

2.1.1 Intelligent Manufacturing Specialty Groups

As intensive professional clusters established by higher vocational colleges in response to the demands of the whole intelligent manufacturing industrial chain, intelligent manufacturing specialty groups are led by core advantageous majors and integrate closely related majors with shared resources and post connection characteristics, featuring strong industrial adaptability and high resource sharing efficiency. The intelligent manufacturing specialty group in this research takes industrial robot technology and mechatronic integration technology as core majors, and integrates supporting majors such as numerical control technology, Internet of Things application technology and industrial big data technology. It aims to cultivate compound technical talents engaged in intelligent equipment commissioning, industrial data mining and intelligent system operation and maintenance[4].

2.1.2 AI Teaching

Different from the popularization of general artificial intelligence theories, AI teaching in this paper refers to a systematic teaching reform that integrates practical technologies including machine learning, digital twin and industrial big data into the whole process of curriculum design, practical training and teaching evaluation based on the practical attributes and post demands of intelligent manufacturing majors. It abandons the traditional theory-oriented teaching mode, focuses on the scenario-based application of industrial AI technology, and cultivates students' practical capabilities in AI tool operation, intelligent fault diagnosis and industrial data analysis, realizing the deep integration of AI technology and professional skills.

2.1.3 Collaborative Development of Industry-Education Integration

The collaborative development of industry-education integration refers to the in-depth educational cooperation among multiple subjects including colleges, enterprises, governments and industry associations based on complementary advantages and benefit sharing, which promotes the effective connection of the education chain, talent chain, industrial chain and innovation chain. The core of the collaboration between AI teaching and industry-education integration lies in the two-way coupling of industrial intelligent demands and college teaching reform. It integrates enterprises' intelligent production scenarios and technical standards into the whole teaching process, and supports enterprises' technological iteration and talent reserve relying on colleges' educational resources, so as to form a virtuous ecological cycle where teaching empowers industrial upgrading and industry feeds back teaching innovation.

2.2 Theoretical Basis

2.2.1 Collaborative Governance Theory

Collaborative governance theory emphasizes that multiple subjects break resource and information barriers and integrate superior resources to maximize systematic operational efficiency, which serves as the core theoretical support of this research. In the collaborative education system, the government undertakes the responsibilities of policy guidance and resource overall planning; colleges focus on talent training and teaching reform; enterprises provide industrial scenarios and technical support; industry associations are responsible for standard formulation and quality evaluation. The multi-subject collaborative linkage effectively makes up for the deficiencies of single-subject education and improves the overall quality of talent training.

2.2.2 Industry-Education Chain Integration Theory

Vocational education and industrial development are naturally symbiotic. The industry-education chain integration theory points out that vocational education must iterate synchronously with industrial upgrading to realize the precise docking of majors with industries, curriculums with posts, and teaching processes with production processes. The intelligent transformation of the manufacturing industry forces vocational education to carry out AI-oriented teaching reform. In turn, the compound talents cultivated by vocational education provide solid talent support for industrial technological upgrading. The two-way interactive relationship between industry and education constitutes the core logical basis for collaborative development[5].

2.2.3 Constructivist Learning Theory

Constructivist learning theory holds that learning is an active knowledge construction process based on real scenarios and practical operation. The collaborative education mode integrating AI teaching and industry-education integration is highly consistent with this theory. By introducing real enterprise intelligent production scenarios and AI practical projects, students can internalize professional knowledge and AI skills in practical operation, which conforms to the growth law of technical and skilled talents in higher vocational education.

3. Development Status and Core Problems

3.1 Development Achievements

3.1.1 Popularization of AI Teaching and Initial Formation of Integrated Curriculum System

Driven by the digital transformation of vocational education, AI technology has been widely applied in the teaching of intelligent manufacturing specialty groups. Most higher vocational colleges have offered general AI courses and industrial AI specialized courses, and high-quality colleges have built modular AI integrated curriculum systems to break traditional professional barriers. The extensive application of digital teaching means such as virtual simulation and digital twin has promoted the transformation of teaching orientation from knowledge-based to competence-based.

3.1.2 Deepened Industry-Education Integration and Iterative Upgrading of Cooperation Modes

Industry-education integration has broken through the shallow cooperation mode dominated by simple internships, and formed three hierarchical development modes including school-enterprise cooperation, industrial college and mixed ownership. Most colleges carry out basic order training and practical training co-construction; high-quality colleges build industrial colleges with leading enterprises; key colleges explore in-depth mixed ownership reform to realize interest binding between schools and enterprises, continuously expanding the depth and breadth of industry-education integration.

3.1.3 Formed Collaborative Education Consensus and Emerging Benchmark Cases

Colleges and enterprises have gradually reached a consensus on collaborative education and actively promoted the coupling of AI teaching and industry-education integration. A number of typical practical cases have emerged in China. Zhejiang University of Mechatronic Engineering has built an AI intelligent vocational education platform; Chongqing Chuangke Vocational College deepens school-enterprise collaboration through equity binding; Fujian College of Information Technology has constructed a group-chain coupling education mode, providing replicable practical paradigms for the industry.

3.2 Core Problems

3.2.1 Superficial Two-Way Integration and Separated Development Dilemma

The integration of AI teaching and industry-education integration in most colleges remains at the shallow splicing stage with prominent separation problems. On the one hand, AI teaching is dominated by general theoretical knowledge, lacking industrial practical cases and post-oriented training projects, which is divorced from the actual demands of intelligent manufacturing posts. On the other hand, current industry-education cooperation barely involves AI curriculum development and intelligent training base construction, failing to empower teaching reform with enterprises' technological and scenario advantages.

3.2.2 Fragmented Curriculum System and Insufficient Integration of AI and Majors

Most colleges only add AI courses sporadically without constructing a systematic integrated curriculum system, resulting in overlapping and discontinuous teaching contents. The curriculum focuses on general AI theories rather than scenario-based application technologies for intelligent manufacturing. The proportion of school-enterprise co-developed project-based and scenario-based teaching materials is low, which cannot keep up with enterprises' cutting-edge technologies. In addition, the absence of unified industrial AI teaching standards leads to the mismatch between college curriculum standards and enterprise post competency requirements[6].

3.2.3 Severe Shortage of Compound Double-Qualified Teachers

Full-time teachers in colleges have solid traditional professional foundation but lack systematic AI theoretical knowledge and industrial practical experience, making it difficult to carry out high-quality intelligent teaching. Enterprise part-time teachers have rich practical experience but insufficient teaching abilities and low enthusiasm for long-term educational participation. Meanwhile, the teacher training system targeting industrial AI is imperfect, and teachers lack effective channels for enterprise temporary training and practical skill iteration.

3.2.4 Insufficient Intelligent Training Resources and Imperfect Training System

Most college training bases are equipped with traditional electromechanical and numerical control equipment, while cutting-edge facilities such as industrial vision systems, digital twin platforms and AI training workstations are insufficient and outdated. On-campus training is based on standardized simulation scenarios which are quite different from complex real production scenarios. Off-campus training is limited to visits and internships, with no in-depth participation of students in enterprise AI R&D and intelligent operation and maintenance. The virtual-real integrated training system has not been fully constructed, failing to solve the high-cost and high-risk pain points of traditional training.

3.2.5 Absence of Long-Term Guarantee Mechanism and Insufficient Collaborative Motivation

Special supporting policies for the collaborative development of AI teaching and industry-education integration are insufficient. There is no sound benefit distribution and risk-sharing mechanism between schools and enterprises, leading to vague return on enterprises' educational investment and low willingness for in-depth cooperation. Besides, college assessment systems do not include AI teaching reform and industry-education integration quality as core assessment indicators, and the lack of incentive mechanisms further restricts the formation of long-term collaborative education mechanisms.

4. Comparative Analysis of Talent Training Modes

4.1 Comparative Analysis of AI Teaching Modes

At present, the AI teaching of intelligent manufacturing specialty groups in higher vocational colleges is divided into three mainstream modes: general education mode, embedded mode and integrated mode, which adapt to colleges at different development stages. The detailed characteristics are shown in Table 1.

Table 1 Comparison of AI Teaching Modes of Intelligent Manufacturing Specialty Groups

Comparison Dimension	General Education AI Teaching Mode	Embedded AI Teaching Mode	Integrated AI Teaching Mode
Core Objectives	To popularize basic AI knowledge and complete universal AI cognition enlightenment	To supplement professional adaptive AI skills and meet basic intelligent post demands	To cultivate compound "manufacturing + AI" capabilities for high-end intelligent posts
Curriculum Setting	Independent general AI courses, separated from professional teaching	AI application chapters embedded in professional courses with shallow integration	Integrated AI curriculum system with specialized exclusive courses
Teaching Contents	Basic AI principles without industrial scenario-based contents	Elementary AI application including machine vision and basic data analysis	In-depth industrial scenario contents including intelligent commissioning, fault diagnosis and data mining
Training Methods	Simple operation of general AI tools and virtual simulation demonstration	Fragmented AI operation modules embedded in traditional training	Scenario-based and project-based training relying on enterprise real projects
Advantages and Disadvantages	Low threshold and easy implementation, but disjointed from majors with low practicability	Controllable cost and strong operability, but shallow integration and unsystematic skills	High industrial adaptability and talent competitiveness, but high construction requirements and investment
Applicable Scenarios	Colleges in the initial reform stage with weak resource foundation	Colleges in transitional stage focusing on basic post talent training	High-quality mature colleges cooperating with leading enterprises

4.2 Comparative Analysis of Industry-Education Integration Modes

According to cooperation depth and subject attributes, industry-education integration is divided into three modes: school-enterprise cooperation, industrial college and mixed ownership, adapting to colleges with different operating foundations.

Table 2 Comparison of Industry-Education Integration Modes of Intelligent Manufacturing Specialty Groups

Comparison Dimension	School-Enterprise Cooperation Mode	Industrial College Mode	Mixed Ownership Mode
Cooperation Subjects	Colleges + small and medium-sized manufacturing enterprises	Colleges + leading enterprises + governments/industry associations	Colleges + leading enterprises + social capital
Cooperation Level	Shallow cooperation focusing on internship, employment and equipment donation	Medium in-depth cooperation covering talent training, curriculum co-construction and resource sharing	Full in-depth integration covering R&D, achievement transformation and benefit sharing
AI Integration Degree	Extremely low, completely separated from AI teaching	Medium, enterprises participate in AI curriculum and training construction moderately	Extremely high, co-construction of AI platforms and joint technological R&D
Advantages and Disadvantages	Low threshold and high flexibility, but loose cooperation and formalization tendency	High resource integration and stable education quality, but dependent on leading enterprise resources	Sufficient collaborative motivation and rapid technology iteration, but complex operation and high investment
Applicable Scenarios	Colleges with weak strength in the initial integration stage	Medium-strength colleges in the growth stage of integration	Key high-quality colleges for high-end talent training

4.3 Enlightenment of Mode Selection

No single mode is universally optimal, and colleges should select and upgrade modes dynamically according to their own development conditions. Colleges with weak foundations can adopt the combined mode of general AI teaching and basic school-enterprise cooperation to complete foundational layout. Medium-strength colleges can upgrade to the mode of embedded AI teaching and industrial college to improve collaborative education accuracy. Key colleges can adopt the advanced mode of integrated AI teaching and mixed ownership integration to build high-end talent training platforms. Continuous mode optimization should be realized with technological iteration and resource accumulation to ensure long-term adaptive development[7].

5. Optimization Paths for Collaborative Development

5.1 Concept Reconstruction: Establish AI-Empowered and Industry-Education Collaborative Education Concept

It is necessary to abandon the traditional solidified education thinking and establish a modern collaborative education concept. First, adhere to AI-oriented empowerment, take the cultivation of AI thinking and practical abilities throughout the whole talent training cycle, and focus on cultivating compound talents adapting to intelligent post demands. Second, strengthen multi-subject collaborative thinking, build an education system guided by the government, dominated by colleges, participated by enterprises and empowered by industries, and realize the precise docking of classrooms with workshops and teaching with production. Third, adhere to post-curriculum coupling, reversely optimize the teaching system based on post competency standards, and transform post demands into teaching objectives, curriculum contents and evaluation criteria to improve students' post competency.

5.2 System Construction: Build a Four-Dimensional Integrated Collaborative Education System

5.2.1 Construct Modular AI Integrated Curriculum System

Breaking professional barriers, this paper constructs a five-tier curriculum system including basic layer, platform layer, direction layer, expansion layer and practice layer. The basic layer offers universal AI courses to consolidate students' theoretical foundation; the platform layer sets up shared professional group AI courses to cultivate general practical skills; the direction layer launches differentiated specialized AI courses targeting core posts to realize precise post-curriculum docking; the expansion layer focuses on cultivating students' cross-border innovation capabilities; the practice layer introduces enterprise real AI projects to strengthen scenario-based training. Colleges should cooperate with leading enterprises to develop project-based and loose-leaf teaching materials, and build digital resource libraries to support intelligent hybrid teaching.

5.2.2 Build Virtual-Real Integrated Intelligent Training System

Colleges should promote the intelligent upgrading of on-campus training bases, add advanced equipment such as industrial vision systems and AI training workstations, and build high-standard intelligent training centers. It is essential to deepen off-campus school-enterprise cooperation, open enterprise intelligent workshops and R&D platforms, and allow students to participate in enterprise AI projects and intelligent operation and maintenance in depth. Relying on VR/AR and digital twin technology, colleges can develop virtual training projects to solve the pain points of high cost and high risk in traditional training, forming a new training pattern dominated by real scenarios and supplemented by virtual simulation[8].

5.2.3 Cultivate Compound Double-Qualified AI Teachers

Colleges should carry out regular AI professional training and enterprise temporary training for full-time teachers, and encourage teachers to obtain industrial AI vocational certificates to improve practical capabilities. A part-time teacher talent pool composed of enterprise AI engineers and technical backbones should be established, with standardized teaching training and incentive mechanisms to improve their teaching enthusiasm. School-enterprise mixed teaching and research teams should be built to carry out joint curriculum development, technological R&D and teaching research, realizing complementary advantages of school and enterprise teachers.

5.3 Mechanism Innovation: Improve the Long-Term Multi-Subject Collaborative Guarantee Mechanism

5.3.1 Construct Four-Party Linkage Governance Mechanism

Clear the responsibilities of the government, colleges, enterprises and industry associations, and establish a regular joint meeting system. The government coordinates resource allocation and policy support; colleges optimize talent training systems and deepen teaching reform; enterprises participate in the whole process of talent training; industry associations formulate industrial standards and release talent demand information dynamically, forming an efficient collaborative governance pattern.

5.3.2 Improve Benefit Sharing and Risk-Sharing Mechanism

Differentiated benefit distribution systems should be formulated for different cooperation modes. Industrial colleges share educational and technological benefits according to resource investment ratio; mixed ownership modes realize interest binding and risk sharing through equity dividends; basic school-enterprise cooperation achieves win-win results through order training and technical services. Clarify the risk responsibility of technology R&D and talent flow to improve the stability of school-enterprise cooperation.

5.3.3 Optimize Two-Way Assessment and Incentive Mechanism

A multi-dimensional evaluation system covering schools, enterprises, teachers and students should be constructed. The effectiveness of AI teaching reform and industry-education integration should be included in college and teacher assessment systems and linked with performance evaluation and professional promotion. Enterprises' educational contributions should be incorporated into social responsibility evaluation and supported by preferential policies such as tax reduction. Students' AI practical achievements and innovative results should be recognized as academic credits to fully stimulate the endogenous motivation of collaborative education.

5.4 Resource Guarantee: Build a Three-Dimensional Support System

Construct a diversified investment mechanism jointly supported by the government, colleges, enterprises and society to guarantee the funding for AI teaching reform and intelligent training base construction. Improve national and local supporting policies to optimize the collaborative education environment. Build a digital industry-education collaborative platform integrating talent docking, resource sharing and technology transformation to break information barriers and empower the high-quality collaborative development of AI teaching and industry-education integration.

6. Conclusion and Prospect

6.1 Research Conclusion

This paper systematically explores the collaborative development path of AI teaching and industry-education integration of intelligent manufacturing specialty groups in higher vocational colleges. The research finds that although the collaborative education effect has been initially achieved, there are still prominent problems including superficial integration, lagging curriculum construction, insufficient compound teachers, scarce intelligent training resources and imperfect guarantee mechanisms, leading to the structural mismatch between talent supply and industrial demands. The three types of AI teaching modes and three types of industry-education integration modes present hierarchical and differentiated adaptive characteristics without universal optimal standards. To realize high-quality collaborative development, colleges should carry out systematic optimization from concept reconstruction, system construction, mechanism innovation and resource guarantee to build a closed-loop and sustainable talent training system adapting to industrial compound talent demands[9].

6.2 Research Prospect

This research is mainly based on qualitative analysis and mode comparison with certain limitations. Future research can construct quantitative evaluation indicators to carry out empirical research and accurately identify the influencing factors of collaborative development. Subsequent studies can further explore the refined operation and risk prevention of mixed ownership integration modes. In addition, with the iterative upgrading of emerging technologies such as generative AI and industrial metaverse, the collaborative education path can be continuously optimized to provide long-term support for high-quality intelligent manufacturing talent training and the construction of a strong manufacturing country.

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