Exploring Collaborative Training Model for Hydrology and Water Resources Curriculum System under Digital Twin Background

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Abstract: The construction of smart water resources is a significant indicator of high-quality development in water conservancy, while digital twin technology serves as the key and core driver for advancing smart water resources. The hydrology and water resources curriculum covers a broad scope of knowledge, involves abstract content, strong theoretical logic, and practical engineering applications. However, existing issues include outdated teaching systems, insufficient collaboration between practical teaching and industry-academia-research integration, inadequate training platform development, and generally suboptimal cultivation of students' higher-order cognitive abilities and problem-solving skills. This paper proposes a collaborative training model integrating practical teaching, industry-education collaboration, resource platform construction, curriculum-based ideological education, and evaluation mechanisms under the digital twin framework. By incorporating ideological education elements into the curriculum, it establishes an industry-academia integrated collaborative training model. This approach provides theoretical support for the development of smart water resources programs in higher agricultural institutions and the cultivation of interdisciplinary talents in water resources management + big data, environmental engineering + Internet of Things, and other composite water resources fields.

Keywords: Smart Water Conservancy; Digital Twin; Industry-Education-Research Collaboration; Ideological and Political Education in Courses; Hydrology and Water Resources Curriculum System

1. Introduction

The development of smart water conservancy stands as a hallmark of high-quality water resource management [1]. The report from the 20th National Congress of the Communist Party of China emphasized the need to 'coordinate the governance of water resources, water environment, and water ecology, and advance ecological protection and management of major rivers, lakes, and reservoirs' [2]. In 2023, China's investments in smart water conservancy information technology reached 21.6-billion-yuan, accounting for 1.80% of total expenditure. Water conservancy informatization has become an inevitable trend in modern water resource development. Digital twin technology aligns with basin requirements and engineering realities, precisely addressing operational

challenges [3]. By focusing on 'enhancing the management capabilities of water conservancy projects and optimizing water resource allocation,' China has launched technological breakthroughs in digital twin water conservancy engineering, establishing a smart water conservancy system with 'Four Preparations' functions [4]. This has become the cornerstone of smart water conservancy development [5]. The establishment of smart water conservancy programs meets the needs of water conservancy universities, particularly agricultural and forestry institutions, for new engineering disciplines and cultivating interdisciplinary professionals. Leveraging the strengths of agricultural universities, these initiatives respond to national strategies and regional demands [6], achieving integration of industry, education, and research. The evolution of smart water conservancy and digital twin technologies toward precision, digitization, and intelligence provides robust technical references for enhancing national water security capabilities.

The hydrology and water resources curriculum system comprises two major modules: Hydrology and Water Resources. The Hydrology module covers courses such as Engineering Hydrology and Hydraulic Calculations, Environmental Hydraulics, River Dynamics, Urban Hydrology, Fundamentals of Ecology, and GIS and Remote Sensing Technology, with a focus on introducing models for watershed generation and convergence, pollutant transport, urban stormwater management, and sediment transport. The Water Resources module primarily includes courses on Water Resources Planning and Conservation, System Analysis, Water-saving Irrigation Technologies, and Climate Change Adaptation Management, emphasizing theories of optimal water resource allocation and sustainable management [7], while introducing models for optimal water resource allocation and management [3]. The hydrology and water resources curriculum covers a broad range of knowledge, with abstract content, strong theoretical logic, and practical engineering applications [8]. However, challenges include outdated teaching systems, insufficient collaboration between practical teaching and industry-academia-research integration, inadequate training platform development, and generally mediocre outcomes in cultivating students 'higher-order cognitive abilities and problem-solving skills [9]. The integration of ideological and political education (IPE) into professional teaching aims to establish a comprehensive educational system that achieves the fundamental goal of 'moral education and talent cultivation' [10]. Therefore, how to 'demand-oriented' incorporate IPE elements, highlight the industry-academia-research collaboration characteristics of higher agricultural institutions, build a coordinated training model for hydrology and water resources courses, and enhance students' application capabilities in numerical simulation, intelligent monitoring, and ecological restoration will help students master core skills in comprehensive water resource management, responding to the call of the ecological civilization era.

2.Challenges in the Hydrology and Water Resources Curriculum System

2.1 Outdated Teaching Framework

The traditional hydrology and water resources curriculum remains theory-centric, with case studies predominantly based on static historical data rather than dynamic digital twin platform examples. Practical components are underdeveloped, as experimental centers lack digital twin platform hardware and software, forcing students to rely on idealized data collection without training in multi-source data fusion. Furthermore, insufficient industry-academia collaboration limits students' exposure to engineering applications integrating digital twins and smart water management. Cultivating interdisciplinary talents in 'water resource management + big data' and 'environmental engineering + IoT' has become pivotal for higher agricultural education.

2.2 Weak Synergy in Practice-Oriented Education and Industry-University-Research Collaboration

Amid the deep integration of smart water management and the 'Three-Water Integration' initiative, the curriculum system faces challenges such as an underdeveloped industry-academia-research coordination mechanism and a disconnect between talent cultivation and industry demands. The insufficient depth of school-enterprise collaboration has prevented enterprises from effectively incorporating cutting-edge technological resources into courses, leaving students with limited understanding of practical applications in smart water management and consequently constrained career planning perspectives. There is an urgent need to optimize the school-enterprise collaborative education mechanism and establish effective pathways for industry-academia-research transformation.

2.3 Insufficient Practical Training Platform Development

While the college has established a basic virtual simulation training platform and internship base, its current functionality remains limited to conventional hydraulic engineering training. The platform lacks specialized modules for digital twin technology, intelligent sensing, and big data analysis. Its limitations in equipment advancement, scenario coverage, and interactive experience hinder its ability to meet the demands of smart and digital education, there by restricting the practical application of new technologies. There is an urgent need to upgrade and expand the smart hydraulic virtual simulation training platform to create an immersive teaching environment that integrates virtual and real-world elements, thereby enhancing students' engineering innovation capabilities.

3. Exploring Collaborative Training Models for Hydrology and Water Resources Courses under Digital Twin Technology

3.1 Reforming the Hydrology Curriculum System with Digital Twin Technology

The integration of smart water management and the 'Three-Water Coordination' strategy will propel the water system's evolution into an intelligent ecosystem characterized by 'knowability, controllability, and optimizability. 'This transformation shifts water management from experience-driven to data-driven approaches while reshaping talent development ecosystems. Traditional curricula struggle to meet the practical demands of smart water industries. For instance, reservoir dam engineering information systems often rely on the San Shui Yuan Xin' a River model and reservoir scheduling models to fulfill the 'Four Preparations' technical requirements for flood forecasting, scheduling, and modern reservoir operation management matrices. By establishing dam breach simulation models, engineers can predict flood risks and enhance downstream flood response capabilities, while guiding students to apply dialectical thinking in balancing engineering projects with environmental protection. Digital twin construction in irrigation districts requires integrating real-time monitoring data (rainfall, water levels, flow rates, sluice gate openings) with existing models for inflow forecasting, water resource allocation, and real-time irrigation demand prediction. This enables dynamic water distribution under an integrated management system covering 'inflow-demand-distribution-regulation.' Extreme rainfall convergence far exceeds urban drainage networks' capacity, causing severe localized flooding [11]. The '7 20' Zhengzhou extreme rainfall forecast based on SKEB ensemble modeling closely aligns with observed precipitation intensity. The synergy between teaching and research to unlock students' innovative potential [7] requires substantial practical wisdom. By implementing a collaborative training model integrating

industry-academia-research collaboration with practical teaching, we can thoroughly explore ideological and political elements in courses. This approach establishes a practical teaching framework for hydrology and water resources curricula, providing theoretical support for developing smart water management programs in agricultural universities and cultivating interdisciplinary talents in composite fields such as 'water resource management + big data' and 'environmental engineering + Internet of Things'.

3.2 Reform of Practical Teaching and Industry-Education-Research Collaboration

The integration of practical teaching with industry-education-research collaboration serves as a pivotal pathway for deepening the convergence between education and industrial development. Through curriculum design, experimental training, case-based instruction, and simulation exercises, practical teaching enhances students 'hands-on skills, problem-solving capabilities, and professional competencies, while driving technological innovation and industrial upgrading. The curriculum design phase encourages students to combine innovative thinking with scientific rigor, boldly proposing novel design solutions and technical measures. This approach cultivates a rigorous, fact-based, and dedicated work ethic, independent problem-solving skills, and collaborative spirit, aiming to develop students' ability to apply models to solve real-world engineering challenges [12]. Practical teaching also reinforces their sense of responsibility and professional ethics [13]. Industry-academia-research integrated training bases introduce corporate projects such as smart water management and three-water coordination, collaborating with enterprises to tackle industry-specific challenges including water resource scheduling, biological remediation of water pollution, and smart irrigation systems [14]. These initiatives develop intelligent water quality and flow monitoring technologies, as well as modular water treatment process courses, to enhance students' practical abilities and sense of responsibility [15]. Industry-education-research collaboration organically links educational, talent, industrial, and innovation chains, establishing a 'dual-subject' education mechanism involving both schools and enterprises. This model optimizes curriculum systems for water-related majors, boosts employment competitiveness, shortens talent development cycles, alleviates structural employment imbalances, and drives industrial upgrading [16].

3.3 Development of Industry-Academia-Research Training Base

The training base is established through partnerships with enterprises such as China Railway Urban Construction Group Co., Ltd. and industry leaders like Hunan Xiangyinhe Sensing Technology Co., Ltd. Leveraging practical projects and technological strengths-including reservoir information systems, ecological restoration of river-lake basins, and digital twin irrigation districts-the initiative collaboratively builds a resource platform. Utilizing the college's existing virtual simulation training labs, it develops intelligent water quality and flow monitoring technologies, along with modular courses on water treatment processes. The program tackles industry challenges such as water resource scheduling, biological remediation of water pollution, and smart irrigation district construction, enhancing students' professional skills and comprehensive application capabilities while addressing the limitations of virtual simulation training platforms.

3.4 Reforming Evaluation Mechanisms

Scientific evaluation of teaching effectiveness requires integrating industry demands with technological trends, adopting innovative designs through multi-dimensional approaches. By

implementing industry-academia-research collaboration methods such as expert lectures and digital twin technology applications, we can enhance students' engineering practice skills, innovative thinking, and professional competencies, thereby improving course quality and talent development. To achieve this, real-time monitoring of teaching outcomes is essential. Collaborative efforts with enterprises should include questionnaire surveys and online course evaluations to establish comprehensive, diversified, and scientific assessment systems. Teaching materials and tools like digital twin simulation systems should be updated based on industry advancements and corporate feedback, enabling continuous optimization of content through ongoing reflection and improvement. An online survey was conducted among 185 students and alumni of Hunan Agricultural University to evaluate the teaching reform of the Hydrology and Water Resources curriculum. The distribution was as follows: freshmen (0.00%),sophomores (8.65%),juniors (39.46%),seniors (30.27%),and graduate students (7.03%).Alumni participation accounted for 14.59%,with proportions of 60.54% from higher education institutions,25.95% from public institutions,5.95% from construction companies,4.86% from design firms, and 2.70% from construction entities. The survey results indicate that 48.65%,49.73%,and 55.14% of respondents believe that the hydrology curriculum design, industry-academia-research collaboration, and research-driven teaching have effectively incorporated ideological and political education elements.Meanwhile,58.38%,53.51%,and 58.92% of respondents consider these approaches highly beneficial for enhancing students' practical skills.

Table 1: Survey Results on the Integration of Industry-Education Collaboration and Ideological and Political Elements in Curriculum.

Survey content	Whether the hydrology course design is helpful to the improvement of students' practical ability			Whether the Course Design of Hydrology Integrates the Elements of Ideological and Political Education		
	option	number of people	proportion	option	number of people	proportion
1	highly	108	58.38%	highly	90	48.65%
2	relatively much more	63	34.05%	relatively much more	66	35.68%
3	Generally small	14	7.57%	Generally small	25	13.51%
4	Weak effect	0	0%	Weak effect	1	0.54%
5	Not detected	0	0%	Not detected	3	1.62%
total		185	100%		185	100%
Survey content	Whether Industry-University-Research Cooperation is Beneficial to the Improvement of Students' Practical Ability			Integration of Industry-University-Research Collaboration into Ideological and Political Elements in Curriculum		
1	highly	99	53.51%	highly	92	49.73%
2	relatively much more	70	37.84%	relatively much more	65	35.14%
3	Generally small	15	8.11%	Generally small	23	12.43%
4	Weak effect	1	0.54%	Weak effect	2	1.08%
5	Not detected	0	0%	Not detected	3	1.62%
total		185	100%		185	100%
Survey content	Whether the research drives teaching is helpful to the improvement of students' practical ability			Whether the Teaching of Scientific Research is Integrated with the Ideological and Political Elements of the Course		
1	highly	109	58.92%	highly	102	55.14%
2	relatively much more	60	32.43%	relatively much more	65	35.14%
3	Generally small	15	8.11%	Generally small	15	8.11%
4	Weak effect	0	0%	Weak effect	1	0.54%
5	Not detected	1	0.54%	Not detected	2	1.08%
total		185	100%		185	100%

4.Conclusion and Prospects

This study demonstrates that practical teaching, industry-academia-research collaboration, the establishment of industry-academia-research training bases, and evaluation mechanism reforms have effectively enhanced students 'professional competencies and innovative thinking. Future efforts should further strengthen university-enterprise partnerships, focusing on cutting-edge technologies

such as hydrological modeling and water resource system analysis. By integrating real-time engineering data and virtual simulation platforms, we aim to develop an integrated 'teaching-research-practice' model. This approach will provide both talent and technological support for national water security while cultivating students' understanding of ecological water security and coordinated flood-drought prevention strategies.

Funding

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