

Current Status and Evolution of Pulp and Paper Undergraduate Education in China

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A paradigm shift of China's pulp and paper industry towards integrated biorefining and sustainability necessitates a fundamental reform of its higher education system. However, a comprehensive overview of the systematic reforms and structural evolution in Chinese undergraduate education has not been established. To fill this gap, this study systematically investigated the current status and evolution of undergraduate programs in Pulp and Paper Engineering in China through a mixed-methods approach, including field research, analysis of training programs from representative universities, and a comprehensive literature review. The major findings reveal three novel reform trajectories: (1) diversified program affiliation across comprehensive, technology, forestry, and vocational institutions; (2) a modularized curriculum structure integrating green papermaking, biorefinery, biomaterials, and intelligent manufacturing; and (3) establishment of frontier-oriented specializations and new majors in biomass utilization. These findings not only signify a strategic pivot in educational philosophy from training traditional papermill engineers to cultivating innovators for the broader bioeconomy but also reveal key implementation challenges, including interdisciplinary curricular integration, faculty readiness, and the depth of industry-academia collaboration. This study provides a novel framework for understanding educational reforms in the pulp and paper industry and offers valuable insights for global stakeholders in forest products education.

DOI: 10.15376/biores.21.2.4198-4206

Keywords: Pulp and paper engineering education; Curriculum system; Biorefinery; Bioeconomy; Sustainability; Chinese higher education

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INTRODUCTION

China's pulp and paper industry, the world's largest in production and consumption, faces significant challenges from resource constraints and environmental pressures (China Paper Association 2024). In response, the industry is undergoing a strategic transformation towards the integration of forest-pulp-paper, biorefining, and sustainable development, aiming to build a green, low-carbon, and circular modern paper industry (Wang 2023; Kong *et al.* 2025). This shift is part of a global movement, as the lignocellulosic biorefinery is widely recognized as a cornerstone for a sustainable bioeconomy, despite facing ongoing challenges and evolving perspectives worldwide (Singh *et al.* 2022). This industrial paradigm shift, further accelerated by China's national "Dual Carbon" goals (carbon peak and neutrality), necessitates a parallel evolution in higher education. Undergraduate programs, forming the cornerstone of talent development,

are thus compelled to undergo fundamental reforms to align with this new national strategic direction.

Pulp and paper engineering education is at a crossroads. Traditional curricula, heavily focused on theoretical instruction and the unit operations of pulping and papermaking, are increasingly perceived as insufficient to address the complexities of the modern bioeconomy and the imperative of sustainability. In Europe and North America, many universities have begun integrating content on biorefinery concepts (bioproducts mill, biokraft mill), lignin valorization, and sustainability assessments into their programs (Clauser *et al.* 2022; Chen *et al.* 2023). A similar imperative for reform is recognized within China, where a number of universities have initiated adaptations (Song *et al.* 2021; Ji *et al.* 2024). However, these reforms are often decentralized and have not been systematically documented or analyzed in the literature, leaving a gap in understanding of the overall trajectory and structural evolution of undergraduate education in response to this national strategic shift.

To bridge this gap, this paper systematically delineates the adaptive adjustments and innovative practices in specialization alignment, curriculum systems, and practical teaching within Chinese undergraduate programs in Pulp and Paper Engineering. This analysis is situated against the backdrop of the industry's transformative shift. Employing a mixed-methods approach that includes field research, consultations with representative Chinese universities, analysis of training programs, literature review, and synthesis of teaching reform projects, this study provides a timely overview of the evolving program affiliation, curriculum reforms, and future development trends. The findings are intended to offer valuable insights for both domestic educational policymakers and the international community concerned with the future of papermaking and forest products education.

Diversified Program Affiliation Across Institution Types

In China, the pulp and paper industry is classified under the “light industry” sector. The term “light” here does not imply lesser importance but rather serves to distinguish it from heavy industry. Light industry, which includes sectors such as food processing, textiles, apparel, leather, papermaking, printing, and daily-use chemicals, primarily focuses on the production of consumer goods and is closely tied to daily life, though it also overlaps with heavy industry in certain areas. Heavy industry, by contrast, supplies the means of production and foundational materials for the national economy, encompassing sectors such as iron and steel, metallurgy, machinery, energy (*e.g.*, power, petroleum, coal, natural gas), and chemicals.

Within China's higher education system, undergraduate programs in Pulp and Paper Engineering are predominantly classified under the major of Light Chemical Engineering. This discipline typically encompasses pulping and papermaking, leather manufacturing, dyeing and finishing, and fine chemicals. However, some universities position their pulp and paper programs within Forest Products Chemical Engineering or Chemical Engineering majors based on their specific academic strengths and characteristics. For instance, universities such as Beijing Forestry University and Central South University of Forestry and Technology anchor their programs in the efficient utilization of forestry resources, emphasizing the cultivation of talent for the entire industrial chain from forest management to paper product manufacturing. In response to industry demand for application-oriented professionals, several higher vocational institutions have recently established undergraduate programs named Modern Paper Engineering Technology. Table 1 provides an overview of representative Chinese

universities offering pulp and paper engineering undergraduate programs, along with their program affiliations.

Table 1. Representative Chinese Universities with Pulp and Paper Engineering Undergraduate Programs and Their Program Affiliations

Category (by Institutional Focus)	Representative Universities and Their Location (Sorted by English Alphabetical Order)	Program Affiliation / Host Major
Comprehensive & Technology Universities	Changsha University of Science & Technology (Changsha), Dalian Polytechnic University (Dalian), Guangxi University (Nanning), Hubei University of Technology (Wuhan), Jilin University of Chemical Technology (Jilin), Kunming University of Science & Technology (Kunming), Qilu University of Technology (Shandong academy of Science) (Jinan), Qiqihar University (Qiqihar), Shaanxi University of Science & Technology (Xi'an), South China University of Technology (Guangzhou), Sichuan University of Science & Engineering (Yibin), Tianjin University of Science & Technology (Tianjin), Zhejiang University of Science & Technology (Hangzhou)	Light Chemical Engineering
Forestry Universities	Beijing Forestry University (Beijing), Central South University of Forestry & Technology (Changsha), Fujian Agriculture and Forestry University (Fuzhou), Nanjing Forestry University (Nanjing), Northeast Forestry University (Harbin)	Light Chemical Engineering or Forest Products Chemical Engineering
Vocational & Technical Institutions	Guangdong Industry Polytechnic University (Guangzhou), Hubei Industry Technology Institute (Wuhan), Sichuan Technology & Business College (Chengdu), Yibin Vocational & Technical College (Yibin)	Modern Paper Engineering Technology

A Modularized Curriculum Structure: Evolution Towards Biorefinery and Sustainability

The undergraduate program in Pulp and Paper Engineering in China follows a credit system. The total credit requirement for graduation typically ranges from 150 to 170 credits, which can be completed in a standard duration of four years with a flexible range of 3 to 6 years. Upon fulfillment of all requirements, students are awarded a Bachelor of Engineering degree. In recent years, the curriculum has been strategically reformed to align with the industry's shift towards integrated, green, and high-value development. As illustrated in Table 2, this evolution is characterized by the modernization of core courses and the introduction of new interdisciplinary subjects. This comprehensive restructuring is a direct response to the ongoing industrial transformation, as detailed in the following subsections.

Curriculum reforms addressing industrial transformation

The transformation of the curriculum is a direct response to the industry's strategic pivot. The introduction of courses such as "Biorefining Technology" and "Biomass Energy and Materials" equips students with the knowledge to drive the transition from traditional papermaking to integrated biomass refineries. Concurrently, courses such as "Carbon Neutrality Technology" and "Artificial Intelligent (AI) Control Technology" directly prepare graduates to tackle the dual challenges of achieving carbon peak and neutrality and advancing intelligent manufacturing.

Emphasis on global competence and practical skills

Complementing the technical curriculum is a strong focus on developing global competence and practical skills. Bilingual instruction, the use of English academic resources, and lectures from international experts are integral to ensuring that graduates can navigate global technological landscapes and collaborate effectively across borders, a pedagogical approach that has been previously advocated for in the Chinese pulp and paper education context (Shen *et al.* 2014).

Practical training is a cornerstone of the program, accounting for 25 to 30% of the total credits. This substantial investment underscores its emphasis on developing hands-on engineering capabilities. The systematic approach, which encompasses laboratory work, course projects, industrial internships, and a capstone graduation thesis (design), ensures that students can effectively translate theoretical knowledge into practical problem-solving skills. This is exemplified by innovative teaching practices that valorize industrial waste to address sustainability goals in chemical engineering education (Borrego and Henderson 2014; Martín-Alfonso and Yáñez 2024).

Specialized tracks for diversified career paths

To cater to diverse career trajectories, many universities have established specialized elective tracks. For instance, Guangxi University offers concentrations in “Biomass Materials and Green Papermaking” and “Cleaner Production and Pollution Control,” while Shaanxi University of Science and Technology provides modules in “Papermaking Process Principles and Technology” and “Biomass Materials”. This modular framework empowers students to customize their education, enabling specialization in fields ranging from traditional process optimization to cutting-edge biomass utilization and process automation.

Establishing Frontier-oriented Specializations and New Majors

In response to the pulp and paper industry’s transition towards biorefining and sustainable development, Chinese universities are reforming their educational programs. Accordingly, traditional undergraduate curricula are being optimized to incorporate emerging interdisciplinary fields such as Green Papermaking Technology, Biomass Energy and Materials, Intelligent Manufacturing and Equipment, and Fiber-based Functional Materials. In recent years, several universities have launched new majors related to biomass utilization. These programs broaden the educational scope and cultivate innovative talent for both the paper industry and the broader biomass sector. Notable examples include Resource and Environmental Science at South China University of Technology, Biomass Materials at Sichuan University, and Biomass Energy and Materials at Dalian Polytechnic University and Shaanxi University of Science & Technology. Concurrently, a growing number of vocational and technical institutions are establishing undergraduate programs named Modern Paper Engineering Technology. These programs focus on applied skills that address immediate industry needs, including advanced process control, intelligent manufacturing, and operational management, while typically introducing biorefining concepts as elective content to provide awareness of broader industry trends.

Table 2. Evolution of the Undergraduate Curriculum in Pulp and Paper Engineering in China

Category	Traditional Core Courses	New/Reformed Courses	Industrial Needs Addressed
Foundational Courses	Advanced Mathematics, University English, Computer Fundamentals, Engineering Drawing, Four Core Chemistry Courses (Inorganic, Analytical, Organic, Physical), Principles of Chemical Engineering	<ul style="list-style-type: none"> • Data Science & Python Programming • Engineering Ethics & Sustainability Concepts 	Foundational knowledge in science and engineering, with enhanced computational thinking and sustainability awareness
Specialized Core Courses	Plant Fiber Chemistry, Pulping Principles and Engineering, Papermaking Principles and Engineering, Pulp and Paper Equipment, Papermaking Pollution Control, Coated & Specialty Paper	<ul style="list-style-type: none"> • Enhanced Plant Fiber Chemistry: deepened focus on lignin, hemicellulose valorization, and biomass nanostructures. • Updated Pulping/Papermaking Principles: incorporation of biotechnology applications, energy-saving technologies, and novel fiber-based products (e.g., paper-for-plastic). • Circular Economy & Waste Valorization 	Biorefinery, sustainability, circular economy, process optimization
Emerging & Interdisciplinary Courses	Traditionally covered within core courses, if at all	<ul style="list-style-type: none"> • Biorefining Technology • Biomass Energy and Materials 	Biorefinery, carbon neutrality, intelligent manufacturing, digital transformation, product diversification
		<ul style="list-style-type: none"> • Carbon Neutrality Technology in the Paper Industry • AI Control Technology in Papermaking • Fiber-based Functional Materials • Life Cycle Assessment (LCA) 	
Skill Development & Practical Training	Emphasizing theoretical instruction	<ul style="list-style-type: none"> • Enhanced Bilingual/Professional English Instruction • Use of Original English Textbooks and Case Studies • Strengthened Practical Training (25-30% of credits): A systematic approach encompassing laboratory work, course projects, industrial internships, and a capstone graduation thesis (design). • Industry-Academia Collaboration: Lectures by corporate engineers, joint training programs, and industry-sponsored projects. • Innovation & Entrepreneurship Education 	Global competence, ability to access cutting-edge international knowledge, hands-on problem-solving skills, and industry readiness.

Challenges and Reflections on the Curriculum Reform

The systematic reforms documented in this study signify a proactive transformation of Chinese pulp and paper engineering education, driven by the twin imperatives of circular economy and Industry 4.0 and 5.0. While these curricular changes align with global trends in engineering education, such as the integration of sustainability and digitalization (Clauser *et al.* 2022; Machado and Davim 2023), their implementation within the Chinese context reveals both notable strengths and critical challenges that warrant deeper examination.

A primary strength lies in the explicit incorporation of circular economy principles through courses such as “Biorefining Technology,” “Biomass Energy and Materials,” and “Life Cycle Assessment.” This shift from a linear, process-focused model to a closed-loop, systems-oriented curriculum reflects a necessary evolution in engineering pedagogy (Machado and Davim 2020). However, merely introducing these topics does not guarantee the development of systems thinking or circular design competence. The literature suggests that without immersive, project-based learning that mirrors real-world complexity, such concepts may remain abstract and poorly applied (Reis *et al.* 2017; Davim 2018). Thus, while the curriculum structure is modular and interdisciplinary, its pedagogical delivery must evolve accordingly to avoid superficial coverage.

Similarly, the integration of AI, intelligent manufacturing, and carbon neutrality technologies responds to the emerging paradigm of Industry 5.0, which emphasizes human-centric and sustainable production (Davim 2025). Yet, this expansion of content introduces the risk of curricular overcrowding. As Borrego and Henderson (2014) note, adding new domains without careful pruning or restructuring can dilute core engineering fundamentals and overwhelm students. The challenge, therefore, is not only what to teach but also what to emphasize, and how to balance breadth with depth in a finite academic timeline.

The strong emphasis on practical training and industry collaboration represents another significant strength, a pedagogical shift that aligns with broader calls for more authentic, experiential learning in engineering education (Davim 2014).

Nevertheless, the effectiveness of such partnerships depends on their depth. Moving beyond conventional internships and guest lectures toward co-created curricula, joint research initiatives, and ongoing professional dialogue would better bridge the gap between academic knowledge and industrial practice, while also advancing progress toward the Sustainable Development Goals (SDGs) (Lantada 2020).

Underpinning all of these reforms is the crucial yet often overlooked factor of faculty readiness. The successful teaching of interdisciplinary, rapidly evolving topics requires instructors who are not only content experts but also skilled in innovative pedagogies. Without systematic support for faculty development and teaching innovation, even the most well-designed curriculum may fail to achieve its intended learning outcomes.

In summary, while the ongoing restructuring and curricular reforms in Chinese pulp and paper undergraduate education, as described in this paper, mark a decisive break from traditional models, their ultimate success hinges on addressing several intertwined challenges: ensuring pedagogical coherence amidst interdisciplinary expansion, deepening industry-academia collaboration, supporting faculty transition, and – above all – developing robust mechanisms to assess whether these reforms truly cultivate the innovative, systems-aware engineers that the future bioeconomy demands.

CONCLUSIONS AND FUTURE PROSPECTS

In summary, China's pulp and paper undergraduate education is undergoing a profound and systematic reform across institutional positioning, curriculum design, and specialization development to actively respond to the industry's paradigm shift from traditional "papermaking" towards "integrated biomass utilization". This reform is characterized by three key trajectories: (1) diversified program affiliation across comprehensive, technology, forestry, and vocational institutions; (2) a modularized curriculum structure integrating green papermaking, biorefinery, biomaterials, and intelligent manufacturing; and (3) the establishment of frontier-oriented specializations and new majors in biomass utilization. The core of this transformation is a strategic pivot from "training engineers for paper mills" to "cultivating innovators for the biorefining industry". These reforms constitute the essential talent foundation for enabling China's transition from a "large pulp and paper producer" to a "strong pulp and paper power".

It is recommended that future efforts focus on the following key directions to further enhance educational quality and relevance: (1) deepening interdisciplinary collaboration, particularly through joint courses with departments of Chemistry, Materials Science, and Environmental Engineering, which aligns with established strategies for driving educational change in Science, Technology, Engineering, and Mathematics (STEM) fields (Borrego and Henderson 2014); (2) integrating advanced technologies, such as virtual simulation and AI, into teaching methodologies; (3) enhancing program internationalization and fostering students' capacity for innovation; and (4) establishing robust university-industry partnerships for lifelong learning, thereby strengthening applied research and the ability to solve complex engineering problems.

ACKNOWLEDGEMENTS

The authors gratefully acknowledge the financial support from the Teaching Reform Project of Changsha University of Science & Technology (Grant No. XJG23-077 and XJG23-025) and the Teaching Reform Research Project of Hunan Province for Postgraduate Education (Grant No. 2024JGZD050 and 2025JGYB160). They also extend their sincere gratitude to Dr. Xuejun Zou (Retired, Former Senior Researcher, FPIinnovations, Montreal, Canada) for his invaluable advice on the upgrading of the pulp, paper, and forest products industries, and on the future development of the bioeconomy.

Use of Generative AI

During the preparation of this work, the authors used DeepSeek (a generative AI tool) to polish and refine the English language expression for improved clarity and fluency. The AI was solely used for textual refinement and did not contribute to the generation of core ideas, data analysis, image/figure creation, or reference collation. After using this tool, the authors reviewed and edited the content as needed and take full responsibility for the final version of the publication.

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Article submitted: October 30, 2025; Peer review completed: Dec. 13, 2025; Revised version received: January 3, 2026; Accepted: March 17, 2026; Published: March 26, 2026.

DOI: 10.15376/biores.21.2.4198-4206