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BUILDING ENGINEERING MICRO-MAJORS AT LOCAL UNIVERSITIES IN THE DIGITAL-INTELLIGENCE ERA: A STUDY OF DEVELOPMENT MECHANISMS AND SUSTAINABLE PATHWAYS IN CHINA

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Abstract: Advances in digital and intelligent technologies have accelerated industrial transformation and upgrading, generating an increasing demand for interdisciplinary, application-oriented engineering professionals. However, traditional degree programs at local universities in China are constrained by lengthy training cycles and slow curriculum renewal, resulting in a pronounced structural mismatch between the supply of engineering talent and evolving industry demands. As a flexible and efficient model of interdisciplinary education, micro-majors have emerged as a promising approach to addressing this mismatch. Considering the distinctive characteristics of engineering education at local universities in China, this study systematically examines the conceptual foundations and defining features of university micro-majors in the era of digital intelligence and identifies the practical challenges associated with the development of engineering micro-majors. On this basis, a three-dimensional framework for their development is proposed, encompassing motivational drivers, operational coordination, and quality assurance. Furthermore, sustainable development pathways are outlined with respect to top-level institutional design, interdisciplinary integration, curriculum resource development, platform sharing, and quality monitoring. This study provides theoretical and practical insights into the high-quality development of engineering micro-majors at local universities in China.
Keywords: Digital-intelligence era; Local universities; Micro-majors; Development mechanism; Sustainable pathways

1 INTRODUCTION

A new generation of information technologies, represented by artificial intelligence, big data, and cloud computing, is profoundly reshaping the global industrial landscape. The rapid growth of the digital-intelligence economy has created new business forms and organizational models. It has also placed unprecedented demands on the knowledge, skills, and professional competencies of higher education graduates [1-3]. To cultivate high-quality professionals capable of responding to evolving labor market needs, micro-majors have emerged as an important innovation in global higher education reform [4]. The concept of the micro-major (commonly translated as 'wēi zhuān yè' in the Chinese higher education context) is related to the specialized course series launched by the US-based edX platform in 2012. They are short-term modular learning programs that certify specific competencies [5-6]. Subsequently, universities in Europe, Australia, and other regions began adopting similar programs to align university curricula more closely with the rapidly changing demands of the labor market [7-8]. Over the years, the global micro-major ecosystem has evolved into several distinct institutional paradigms [9], including the decentralized, market-driven innovation model represented by the United States [10], the framework-integrated standardization initiatives implemented in the European Union and Australia [11-12], and the state-led development strategies characteristic of East Asian economies.

China's exploration of micro-major systems has undergone a notable transition from bottom-up experimentation to state-led, top-down, and systematic implementation [13]. In 2018, the Ministry of Education of China formally endorsed the development of micro-majors in higher education institutions for the first time through in the 'Opinions on Accelerating the Development of High-Quality Undergraduate Education and Comprehensively Enhancing Talent-Cultivation Capacity'. The policy initiated a period of rapid experimentation and expansion among Chinese universities. In 2024, the Shanghai Municipal Education Commission issued the Guidelines for 'the Development of Micro-Majors in Shanghai Higher Education Institutions', specifying that micro-majors should be characterized by limited credit requirements, streamlined curricula, a clearly defined focus, interdisciplinarity, and flexibility. In 2025, the Ministry of Education further incorporated micro-major development into the national education strategy through the 'Employment Ability Enhancement Double Thousand Plan Initiative'.

As a major component of China's higher education system, local universities bear primary responsibility for cultivating advanced application-oriented professionals who can contribute to regional economic and social development. However, the conventional four-year training model adopted by traditional engineering programs is characterized by long training cycles and slow knowledge renewal. Curricula are updated relatively slowly, and instructional content is often disconnected from recent industrial and technological developments, making it difficult for such programs to respond effectively to the "new normal" of accelerating technological iteration and rapidly evolving occupational competency requirements (Table 1). Consequently, the structural contradiction between graduate employment difficulties and persistent shortages of suitably qualified professionals has become increasingly pronounced [14]. In engineering education at local universities, micro-majors represent not only an effective means of addressing the mismatch between talent supply and industrial demand but also a strategic mechanism for transforming engineering education from a discipline-oriented model to a demand-oriented model and from knowledge transmission to competency development [15]. Nevertheless, compared with comprehensive research universities, local universities face clear disadvantages in terms of financial investment, faculty capacity, platform resources, and institutional reputation. The development of engineering micro-majors at these institutions is therefore subject to more complex practical constraints, highlighting the urgent need for systematic institutional design and the optimization of implementation pathways.

Table 1 Comparison of Conventional Degree Programs and Micro-Majors in China

Dimension	Conventional Degree Program	Micro-Major
Duration of Study	4 years (undergraduate degree)	1-2 years
Credit Requirements	120–160 credits	10–20 credits
Curricular Characteristics	Systematic and theory-oriented	Modular and practice-oriented
Disciplinary Boundaries	Relatively fixed	Interdisciplinary integration
Responsiveness to Change	Relatively slow	Rapidly responsive to change
Type of Credential	Academic degree certificate	Micro-major certificate/certificate of completion

2 DEFINING CHARACTERISTICS OF UNIVERSITY MICRO-MAJORS IN THE DIGITAL-INTELLIGENCE ERA

University micro-majors in the digital-intelligence era have evolved beyond the rudimentary format of early online course clusters into a new paradigm of talent development that deeply integrates digital technologies, industrial demands, and educational principles. Their defining characteristics can be examined across five dimensions.

2.1 Frontier-Oriented Program Design

Micro-majors focus on emerging digital and intelligent technologies and evolving trends in industrial transformation. Course modules are developed around emerging fields such as AI, new-energy, IoT, and the digital economy, thereby incorporating the latest disciplinary developments, research findings, and technological advances into the curriculum. Compared with conventional degree programs, micro-majors can respond more rapidly to technological change, address industry-specific skills shortages, and equip students with up-to-date professional competencies. This frontier-oriented approach requires teaching teams to continuously monitor developments in major industries and changes in market demand, anticipate future technological trajectories, and dynamically update course content.

2.2 Flexibility of the Educational System

Micro-majors are highly flexible in terms of program duration, curriculum structure, and instructional methods. They typically last between one and two years, require 12–20 credits, and comprise approximately 4–10 courses. Instruction commonly adopts a blended model that combines online theoretical learning with offline practical training, enabling students to adjust their learning progress according to their individual pace and circumstances. Curricula can also be dynamically revised in response to academic advances, industrial needs, and disciplinary developments. This flexibility enables students to broaden their knowledge base without disrupting their primary degree studies and allows universities to use micro-majors as experimental platforms for developing new academic programs.

2.3 Interdisciplinary Integration

Micro-majors transcend conventional disciplinary boundaries by systematically integrating knowledge, methods, and technologies from different fields, thereby establishing a composite knowledge structure that encompasses disciplinary expertise, digital-intelligence competencies, and industry-specific applications. For example, a micro-major in Intelligent Information Technology may integrate established disciplines such as electrical engineering, computer science, and mechanical engineering with emerging fields including intelligent sensing, artificial intelligence, and machine learning. Similarly, a micro-major in Sustainable Building may incorporate multidisciplinary content related to renewable energy, structural engineering, the built environment, and Internet of Things-enabled monitoring. Such integration not only addresses students' demand for interdisciplinary learning but also facilitates the effective consolidation and sharing of educational resources across universities.

2.4 Practice-Oriented Integrated Training

Practical training is a defining feature that distinguishes micro-majors from conventional theory-centered education. Through university–industry collaboration, micro-majors establish integrated industry–education platforms and incorporate enterprise-based pre-employment training, real-world project cases, and frontline production scenarios into their curricula. Enterprise engineers may be appointed as adjunct instructors, while universities and companies may jointly establish modern industry colleges, thereby strengthening the integration of theoretical instruction and project-based training. Some universities have also introduced virtual simulation technologies, including augmented reality, virtual reality, and mixed reality, to create immersive practical learning environments. These technologies help address persistent challenges in practical education, including limited access to authentic workplace settings, confidentiality constraints, and substantial safety risks.

2.5 Personalized Learning Pathways

Micro-majors enable students to independently select course modules according to their interests, strengths, and career objectives, thereby supporting the targeted development of individualized knowledge structures. In instructional practice, intelligent learning platforms can provide adaptive learning pathways, personalized knowledge recommendations, and differentiated academic support. In assessment, micro-majors move beyond conventional standardized examinations by integrating formative assessment with competency-based evaluation and tailoring assessment criteria to the distinctive characteristics of each program. In teacher–student interaction, small-class instruction enables instructors to develop a detailed understanding of each student's learning progress and provide individualized guidance.

3 CHALLENGES IN DEVELOPING ENGINEERING MICRO-MAJORS AT LOCAL UNIVERSITIES

Although local universities have made initial progress in developing engineering micro-majors, they continue to face multiple practical challenges arising from constraints in institutional resources and the broader policy and governance environment.

3.1 Inadequate Investigation of Industry Needs and Pronounced Curriculum Homogenization

Before establishing micro-majors, some universities fail to conduct systematic and in-depth investigations of enterprise research and development departments, production units, and testing facilities. Consequently, they lack an accurate understanding of the technical requirements and competency expectations of different types of enterprises. Assessments of industry needs are often conducted in a formalistic and superficial manner, resulting in overly generic program titles and a substantial disconnect between curriculum content and actual industrial demands. Some micro-majors merely reorganize or rename existing courses without restructuring the underlying knowledge system in accordance with specific industry requirements. As a result, students may encounter considerable overlap between micro-major courses and their primary undergraduate curricula, with limited substantive improvement in their professional competencies.

3.2 Limited Enterprise Engagement and Superficial Industry–Education Integration

The inherently application-oriented nature of micro-majors makes enterprises indispensable participants in their development and implementation. In practice, however, enterprise involvement is generally limited to the delivery of occasional lectures or nominal participation as program advisors, with few enterprise professionals substantively engaged in core activities such as curriculum design, instructional implementation, student assessment, and program evaluation. Universities also lack effective mechanisms for transforming authentic enterprise projects and technical challenges into educational resources. Consequently, a persistent divide remains between classroom instruction and industrial practice, and industry–education integration has yet to advance from the simple aggregation of institutional resources to substantive, coordinated, and synergistic collaboration.

3.3 Homogeneous Faculty Composition and Insufficient Interdisciplinary Teaching Capacity

The interdisciplinary and practice-oriented nature of micro-majors places higher demands on the professional expertise and instructional capabilities of faculty members. Ideally, teaching teams should comprise university-based theoretical instructors, faculty members from multiple disciplines, and industry mentors. In practice, however, teaching responsibilities are assumed almost entirely by university faculty, whereas industry mentors are generally appointed on a temporary or project-based basis without long-term planning or institutional support. Although university instructors are typically proficient in theoretical instruction, many lack practical industry experience and interdisciplinary knowledge. Consequently, they often experience difficulties in effectively implementing project-based, case-based, and practice-oriented teaching.

3.4 Inadequate Management Systems and Weak Incentive Mechanisms

The development of micro-majors is a complex and systematic undertaking that requires faculty members to invest substantially more time and effort than is typically required for conventional course development. Nevertheless, most universities have not established corresponding mechanisms for workload compensation, performance recognition, or the consideration of micro-major contributions in academic promotion and professional title evaluation. This lack of institutional recognition weakens faculty members' motivation to participate in micro-major development. Furthermore, the development of micro-majors lacks robust, sustained, and comprehensive incentive mechanisms. Some programs rely heavily on short-term policy initiatives and may stagnate once policy attention declines or resource support diminishes, thereby undermining their long-term sustainability.

4 DEVELOPMENT MECHANISMS FOR ENGINEERING MICRO-MAJORS AT LOCAL UNIVERSITIES IN THE DIGITAL-INTELLIGENCE ERA

To address the challenges identified above, local universities should establish an integrated "motivation–operation–constraint" mechanism for the development of engineering micro-majors, thereby ensuring that the development process is strategically guided, collaboratively implemented, and institutionally regulated.

4.1 Motivational Mechanism: Coordinated Drivers of Multiple Demands

The development of micro-majors is driven by the convergence of multiple demands. First, national strategies provide overarching policy guidance. National priorities, including artificial intelligence, carbon peaking and carbon neutrality, the digital economy, and the green economy, have generated an urgent demand for large numbers of interdisciplinary engineering professionals. Owing to their flexibility and adaptability, micro-majors can respond rapidly to the need to build talent reserves in these strategically important fields. Second, industrial and market demand provides a strong external impetus. Technological upgrading within local industrial clusters has created new competency requirements for emerging occupations. By shortening training cycles and restructuring curriculum modules, micro-majors can effectively alleviate the mismatch between the supply of qualified professionals and evolving labor-market demand. Third, institutional reform within universities constitutes an important internal driving force. Because conventional degree programs often respond slowly to industrial transformation, micro-majors can serve as experimental platforms for developing new academic programs and provide opportunities for interdisciplinary integration and innovation in talent-development models. Fourth, students' developmental needs represent a significant individual-level driver. Accelerated knowledge renewal and increasingly diverse career trajectories have intensified students' demand for personalized and sustainable professional development. Micro-majors can provide the interdisciplinary knowledge and competencies required for career adaptation, mobility, and transition. These four driving forces interact with and reinforce one another, thereby creating a virtuous ecosystem for the sustained development of micro-majors.

4.2 Operational Mechanism: Resource Coordination and Sharing

The operational mechanism centers on the effective integration and optimal allocation of educational resources. First, interdisciplinary curriculum coordination should be strengthened. Institutional and departmental barriers should be removed, and mechanisms for the joint provision of courses across disciplines should be established. Faculty expertise and teaching platforms should be shared to facilitate the efficient circulation of curriculum resources within universities. Second, in-depth university–industry integration should be promoted. Universities and enterprises should jointly formulate program-development plans and collaboratively develop curriculum resources and practical training projects. Enterprises should participate substantively in the formulation of curriculum standards and the implementation of teaching activities, thereby establishing a modular division of responsibilities in which core courses are delivered by university faculty, practical courses are taught by enterprise engineers, and case-based courses are offered by industry mentors. Third, regional interinstitutional collaboration should be strengthened. Through formal cooperation agreements, universities can establish joint management bodies and credit-recognition mechanisms, collaboratively develop curriculum resources, and share faculty expertise. Such arrangements can provide students with flexible cross-institutional and cross-regional learning pathways. Fourth, digital platforms should be employed to improve operational efficiency. Online learning management systems, virtual teaching and research communities, and intelligent learning platforms can support the digital administration of the entire educational process, including course enrollment, practical-training reservations, credit recognition, and certificate issuance, thereby enhancing the efficiency of resource allocation and utilization.

4.3 Constraint Mechanism: Quality Control Throughout the Entire Process

The constraint mechanism is intended to ensure the quality, standardization, and sustainable development of micro-majors. First, clear standards for program entry and approval should be established. These standards should assess the alignment between training objectives and industrial needs, the coherence of the curriculum system, the interdisciplinary composition of the teaching team, and the adequacy of practical training conditions, thereby preventing the indiscriminate establishment of programs merely in response to prevailing trends. Second, process-monitoring requirements should be strengthened. A multidimensional quality-monitoring system encompassing classroom observation, peer review, student evaluation, and enterprise feedback should be established. Data on classroom interaction, learning outcomes, and other relevant indicators should be collected in real time to support continuous quality improvement. Third, rigorous standards for program completion and student assessment should be formulated. These standards should evaluate students' knowledge acquisition, technological application capabilities, innovative capacity, and occupational adaptability. Thirdparty evaluation or industry certification may also be introduced to enhance the credibility and recognition of micro-major certificates. Fourth, credit management should be standardized. Clear rules should be established for the acquisition, accumulation, transfer, and recognition of micro-major credits. Credit-recognition mechanisms among micro-majors, primary degree programs, and minor programs should also be explored to facilitate their effective articulation with formal degree education.

5 SUSTAINABLE DEVELOPMENT PATHWAYS FOR ENGINEERING MICRO-MAJORS AT LOCAL UNIVERSITIES IN THE DIGITAL-INTELLIGENCE ERA

Building on the framework of development mechanisms outlined above, local universities should systematically advance the development of engineering micro-majors across six dimensions, thereby shifting the emphasis from quantitative program expansion to qualitative enhancement.

5.1 Optimizing the Overall Top-Level Design of “Digital Intelligence + Engineering”

Local universities should align the development of micro-majors with regional industrial positioning and establish regular mechanisms for assessing industry needs. Micro-major specializations should be strategically designed in response to the digital and intelligent transformation requirements of local pillar industries and strategic emerging industries. For example, micro-majors in Intelligent Information Technology may be developed to serve the electrical industry; micro-majors in Sustainable Building and Intelligent Construction may be established for the construction industry; and micro-majors in New Energy Vehicle Technology may be offered to support the automotive industry. Such targeted planning can ensure close alignment between micro-major programs and local industrial demands. At the institutional level, universities should strengthen top-level planning by formulating regulations governing the development and management of micro-majors and clearly specifying program-approval standards, development procedures, divisions of responsibility, and funding arrangements. Dedicated funding mechanisms should also be established to support curriculum development, the recruitment of industry instructors, and the construction of practical training bases, thereby providing the institutional and material resources required for the sustainable development of micro-majors.

5.2 Promoting Interdisciplinary Integration in “Digital Intelligence + Engineering”

Interdisciplinary integration is a fundamental requirement for cultivating engineering professionals in the digital-intelligence era. First, universities should formulate interdisciplinary development plans that identify priority areas and potential points of convergence associated with “intelligence +,” “green +,” and “digital +,” thereby transcending conventional disciplinary boundaries. Second, a progressive curriculum system should be designed around three interconnected course clusters: a fundamental theory module, a technological tools module, and an integrated practice module. Collectively, these modules should constitute a structured map of knowledge and competencies. Third, interdisciplinary teaching teams should be established by encouraging faculty members from different disciplines to jointly develop courses and by involving enterprise engineers in teaching activities, thereby creating a dynamic and complementary dual-qualified teaching structure that integrates academic expertise with industry experience.

5.3 Developing High-Quality Curriculum Resources for “Digital Intelligence + Engineering”

Curriculum resources constitute the primary vehicle for micro-major development. First, curriculum content should be optimized by constructing a knowledge map aligned with the positioning and objectives of each micro-major, selecting or compiling high-quality teaching materials, and transforming the latest industrial technical standards, engineering cases, and project data into educational resources. Second, instructional design should be innovated through challenge-based project learning and task-driven teaching methods. Authentic engineering problems should be decomposed into progressively structured learning tasks, enabling students to develop professional competencies through the resolution of practical problems. Third, curriculum resources should be digitized through the production of instructional videos for core courses and the development of digital resources, including exercise banks, case repositories, and virtual experiment databases, thereby supporting self-directed learning and repeated practice. Fourth, learning arrangements should be made more flexible by providing diverse learning pathways, including live online instruction, recorded course playback, on-campus practical training, and enterprise-based job rotation, to accommodate students’ varying schedules, learning needs, and preferences.

5.4 Establishing Open and Shared Platforms for “Digital Intelligence + Engineering”

Platforms serve both as repositories for high-quality curriculum resources and as essential infrastructure for the development of professional competencies. First, interdisciplinary collaboration platforms should be established to encourage faculty members and students from different fields to jointly address complex engineering problems, thereby promoting knowledge exchange, disciplinary integration, and collaborative innovation. Second, online learning platforms should be developed by integrating functions such as course-video delivery, interactive discussion, assignment submission, competency assessment, and certificate management, thereby enabling the visualization, documentation, and continuous tracking of the learning process. Third, university–industry collaboration platforms should be jointly established through organizational arrangements such as modern industry colleges, doctoral innovation stations, and engineering technology centers. These platforms can transform enterprise research and development projects into teaching cases and provide students with opportunities to engage with authentic engineering environments. Fourth, regional resource-sharing platforms should be developed through participation in, or the establishment of, interuniversity micro-major alliances, thereby facilitating the cross-institutional circulation of high-quality curriculum resources and the mutual recognition of academic credits.

5.5 Strengthening the Quality-Monitoring System for "Digital Intelligence + Engineering"

Quality monitoring is essential for the sustainable development of micro-majors. First, a comprehensive evaluation indicator system should be established to encompass curriculum design, teaching implementation, learning outcomes, employment quality, and enterprise satisfaction, thereby avoiding the limitations associated with relying exclusively on graduate employment rates. Second, learning analytics technologies should be introduced to track students' learning behaviors through big-data analysis and accurately evaluate the extent to which the objectives specified in the competency map have been achieved. Barriers among educational datasets should also be removed, and a tripartite data pool involving universities, enterprises, and accreditation bodies should be established. Third, teaching-management standards should be improved by clearly defining the responsibilities of university-level teaching administration departments, individual schools or departments, micro-major directors, course instructors, and enterprise mentors, while optimizing the application of digital and intelligent tools throughout the management process. Fourth, a continuous improvement mechanism should be established. Universities should regularly track graduates' career development, collect feedback from employers, and incorporate data on occupational competency requirements into curriculum optimization, thereby establishing a closed-loop management process encompassing evaluation, feedback, and improvement.

6 CONCLUSION

In the digital-intelligence era, micro-majors provide local universities with an important mechanism for addressing the mismatch between the supply of and demand for engineering talent, deepening industry–education integration, and advancing New Engineering Education. They also offer an effective pathway through which universities can support the high-quality development of regional industries. The development of engineering micro-majors at local universities represents a systemic reform involving talent-development models, faculty structures, curriculum systems, and institutional governance. It should therefore extend beyond the superficial aggregation or repackaging of existing courses. Instead, universities should respond proactively to regional industrial needs by establishing scientifically grounded development mechanisms encompassing motivational drivers, resource coordination, and quality assurance. Through the precise alignment of educational provision with industry needs, substantive industry–education integration, robust institutional support, and continuous quality improvement, engineering micro-majors can shift from quantitative expansion toward qualitative enhancement. In doing so, they can fully realize their educational and societal value while providing regional industrial transformation and upgrading with a larger pool of highly qualified, interdisciplinary engineering professionals whose competencies are closely aligned with evolving industry requirements.

COMPETING INTERESTS

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