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Innovative and Practical Integration of Professional Courses in Urban Spatial Planning Oriented towards Digital Twin

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Abstract: Digital twin has been widely adopted across all stages of modern urban spatial planning. It helps the sector move beyond conventional static planning modes and evolve toward data-supported intelligent planning featuring dynamic simulation. This industrial shift also puts forward new standards for talent training in urban spatial planning. At present, the existing curriculum for this major suffers from scattered content, inadequate integration of digital technologies and weak interdisciplinary links, which can hardly meet the talent requirements in the digital twin era. Combined with the technical features of digital twin and the overall reform of territorial spatial planning, this paper analyzes the practical grounds for curriculum integration. It constructs a tiered curriculum framework with progressive vertical logic and an interconnected horizontal layout. The study also explores feasible solutions covering virtual-physical combined teaching, curriculum content restructuring, interdisciplinary teacher teamwork, and a full-cycle assessment mechanism. By optimizing the curriculum framework and upgrading teaching modes, this work realizes effective integration of different specialized courses. The research outcomes can offer practical references for cultivating competent urban spatial planning professionals, adapting to digital twin applications.

Keywords: Digital twin; Urban spatial planning; Curriculum integration; Territorial spatial planning; Specialized teaching

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1. Introduction

As a core technological pillar for smart city development, digital twin runs through the full lifecycle of urban spatial planning, including preliminary research, scheme design, simulation analysis, as well as later-stage operation and maintenance. It has become an essential skill set that modern planning practitioners must master. As China fully rolls out the unified territorial spatial planning system, colleges need to adjust training objectives, course content and practical arrangements for urban spatial planning majors to keep pace with industrial changes.

However, the current curriculum still has prominent defects. Basic and core courses operate independently, theoretical learning is separated from practical training, and traditional teaching content fails to effectively combine emerging digital

technologies. These problems greatly restrict the cultivation of compound planning talents. Taking the digital twin as the core orientation, this paper discusses the ideas and implementation approaches of curriculum connection for urban spatial planning majors. Through overall system restructuring and teaching innovation, the research breaks down inter-course barriers and enables specialized teaching to better align with real industrial demands.

2. New demands for curriculum connection under territorial spatial planning reform

2.1. Restructured planning system requires integrated knowledge systems

The nationwide implementation of the "five-level and three-category" territorial spatial planning system has thoroughly reshaped the working framework and knowledge system of urban spatial planning. Accordingly, professional courses need to form logically connected knowledge chains. Traditional urban planning courses are divided by individual research fields, resulting in fragmented knowledge points in comprehensive planning, detailed planning and special planning. Such a mode cannot satisfy the core requirements of overall territorial arrangement and multi-plan coordination.

Current planning practices have fully incorporated new concepts and norms of territorial spatial planning. The new system emphasizes the coordinated arrangement of ecological protection, land use, transportation network, and landscape layout. It requires course content to break disciplinary boundaries and form a complete knowledge chain covering macro regional layout and micro site design [1]. Students majoring in urban spatial planning should take territorial spatial planning as the main thread, sort out the internal relations between knowledge points of different courses, and achieve systematic knowledge docking via vertical and horizontal integration. In this way, students can establish a holistic thinking pattern covering all territorial spaces and spatial elements.

2.2. Technological revolution drives upgrading of competency training systems

The technological revolution led by digital twins has promoted the upgrading of competency training modes for urban spatial planning majors. Traditional planning work mainly relies on two-dimensional drawings and qualitative analysis. In contrast, modern planning posts require practitioners to master a full range of capabilities, including multi-source data collection, three-dimensional modeling, dynamic simulation and intelligent decision-making.

The transformation of competency orientation requires teaching to resolve the long-standing separation between theoretical learning and technical training. A digital twin can collect massive basic data for urban public space planning and convert raw data into usable information. Given this technical feature, teaching activities need to foster two types of capabilities simultaneously: technical skills such as data processing, virtual simulation, and spatial analysis, as well as professional capabilities including planning, design, and scheme optimization [2]. Curriculum connection should focus on core competencies related to digital twin, rearrange the whole training path, and build a progressive learning sequence linking basic technical courses, professional theoretical courses and practical application courses.

2.3. Industrial talent needs a guide for in-depth integration of practical teaching

The development of smart cities and intelligent territorial governance has raised higher requirements for the practical teaching of planning majors. The industry is in urgent need of interdisciplinary talents who possess solid planning theories, proficient digital skills and rich field experience. Nevertheless, most existing practical teaching tasks are based on hypothetical cases, which are divorced from real working scenarios and fail to match industrial talent standards.

Regional space is a typical complex adaptive system, consisting of natural organisms, socioeconomic units, administrative organizations, geographic units and digital twin spatial carriers. Such complex practical scenarios demand that practical teaching be connected with real projects and add dedicated training modules for digital twin operation[3]. Guided by industrial demands, colleges should link on-campus training, university-enterprise cooperation and field project practice. The synchronous development of theoretical teaching, technical training and practical exercises will effectively improve students' adaptability to actual jobs.

3. Construction of an integrated curriculum system for digital twin-oriented urban spatial planning

3.1. Vertical progressive layout: Three-tier curriculum from foundation to practical application

To realize effective curriculum integration, this study establishes a three-tier progressive curriculum system, with a digital twin running through all teaching links. The framework clearly defines teaching positioning, core content, competency objectives and internal connection logic of each tier. It forms an interconnected, coordinated and closed-loop course chain, which fundamentally solves the problems of discontinuous teaching and jump-style skill training in traditional courses.

The foundational tier lays the groundwork for the whole curriculum system, focusing on basic urban planning theories and fundamental digital twin technologies. It mainly includes Surveying, Geographic Information System Principles, Spatial Data Processing, Architectural Drawing and Urban Planning Basics. This tier aims to help students build capabilities in data collection, spatial expression, geographic information analysis and basic planning cognition. Courses at this stage embed elementary digital twin technologies, such as multi-source geographic data acquisition, 2D-to-3D model conversion and basic GIS tool operation. They provide solid theoretical and technical support for subsequent courses and serve as the prerequisite for the entire curriculum system.

The core tier acts as the central hub of curriculum integration, focusing on a deep combination of digital technologies and planning expertise. Main courses cover Urban Spatial Planning, Digital Twin City Modeling, Urban Transportation Planning, Ecological Space Planning and Urban Design. This tier targets the cultivation of students' capabilities in scheme design, 3D modeling, simulation analysis and professional evaluation. Teachers integrate core digital twin technologies into professional teaching, including urban 3D model construction, spatial dynamic simulation, intelligent evaluation of planning schemes and traffic flow simulation. It realizes in-depth integration of planning theories and digital technologies, inherits competency training from foundational courses and provides support for practical training in application courses.

The application tier faces real industrial needs and job requirements. Related courses include Comprehensive Planning and Design Practice, Smart City Operation and Management, Digital Landscape Planning and Frontier Topics of Territorial Spatial Planning. This tier focuses on developing students' abilities in project operation, full-cycle operation and maintenance, team collaboration and intelligent governance. Teaching content centers on digital twin platform operation, implementation of real planning projects and dynamic management of planning results. Students can convert theoretical knowledge and technical skills into practical working abilities, completing the transition from campus learning to industrial practice.

The three-tier system takes the digital twin as the main line to achieve seamless vertical connection. Teaching content and competency objectives are upgraded step by step, fully adapting to the whole workflow of digital twin-based planning.

Table 1. Vertical connection of three-tier courses for the urban spatial planning major

Course Tier	Core Courses	Competency Training Objectives	Digital Twin Integration Content	Connection Logic
Foundational Tier	Surveying, GIS Principles, Spatial Data Processing, Architectural Drawing	Master data collection, spatial analysis, basic modeling and planning cognition	Multi-source data collection, GIS spatial analysis, 2D-3D conversion, basic geographic information processing	Lay a foundation and provide technical & theoretical support for core courses
Core Tier	Urban Spatial Planning, Digital Twin Modeling, Urban Transportation Planning	Master planning design, model building, scheme simulation and professional evaluation	Urban 3D modeling, spatial simulation, intelligent assessment of planning schemes, digital traffic flow simulation	Serve as the central link, inherit basic capabilities and cultivate core professional competencies.

Course Tier	Core Courses	Competency Training Objectives	Digital Twin Integration Content	Connection Logic
Application Tier	Planning & Design Practice, Smart City Management, Digital Landscape Planning	Build capabilities in project operation, full-cycle maintenance and team collaboration.	Digital twin platform operation, planning implementation, simulation, intelligent governance, full-cycle project management	Realize ability transformation, connect industrial demands and form a complete competency system.

3.2. Horizontal integration: An interdisciplinary collaborative mechanism for course content

A digital twin is a typical interdisciplinary technology. For this reason, urban spatial planning courses need to break the boundaries between planning, surveying and mapping, computer science, landscape architecture and traffic engineering. Through horizontal content integration and interdisciplinary cooperation, colleges can build a unified knowledge system for digital planning.

High-precision three-dimensional spatial information is the cornerstone of digital twin city construction. The collection, processing, modeling and application of such information involve surveying & remote sensing, data algorithms, computer modeling and urban planning. Single-discipline teaching can no longer meet the learning needs of digital twin-oriented planning education [4].

The horizontal integration mechanism takes the full workflow of digital twin urban planning as the core scenario, and adopts the strategies of module splitting, knowledge embedding, interdisciplinary fusion and project-driven integration to reorganize cross-disciplinary course content. First of all, teachers split core knowledge points of different disciplines, and embed digital twin-related technologies, including 3D laser scanning, oblique photogrammetry, data cleaning, CIM/BIM modeling, and virtual simulation into surveying, computer, and planning courses. Secondly, professional theories concerning urban spatial layout, ecological protection, traffic organization and landscape design are added into technical courses, realizing two-way integration of professional knowledge and digital skills.

Thirdly, repeated content and knowledge gaps between different courses are eliminated. For instance, road network design in traffic planning is combined with traffic flow simulation based on a digital twin; plant layout design in landscape planning is integrated with digital twin scene construction for landscapes, so as to avoid content redundancy. Finally, colleges take digital twin planning projects as a means to integrate cross-disciplinary content and set up comprehensive projects covering multiple courses. Students can learn to apply multidisciplinary knowledge in project practice, and form a complete content chain covering data collection, modeling analysis, scheme design, simulation evaluation and operation management.

Supported by this interdisciplinary collaborative mechanism, urban spatial planning teaching shifts from the traditional mode of independent single-discipline teaching to integrated interdisciplinary training. Students can systematically master combined knowledge of digital technologies, planning theories, ecological concepts and practical skills, which provides solid support for cultivating interdisciplinary planning talents in the digital twin era.

4. Practical implementation strategies for digital twin-oriented curriculum integration

4.1. Construction of virtual-physical integrated teaching scenarios

Building integrated virtual and real teaching scenarios is the key to realizing curriculum integration. Supported by digital twin technologies, colleges can create a unified teaching environment combining virtual simulation and real field scenarios, and bridge the gaps between theoretical learning, practical training and industrial work.

With the help of oblique photogrammetry, 3D laser scanning and VR simulation technologies, colleges can build a city-scale digital twin teaching platform to restore real urban spatial environments. On this platform, students can finish the whole process of data collection, planning, design, and simulation verification in virtual environments. Before class,

students preview basic knowledge via the digital twin platform. During class, virtual scenarios are adopted to carry out core planning and design training. After class, teaching is connected with real planning projects to complete practical tasks of application-oriented courses. This full-scenario and full-process integrated teaching effectively solves the problem of disconnection between theory and practice in traditional teaching.

4.2. Deep fusion between digital technologies and planning theories

Restructuring course content is the core link to implement curriculum integration. It is essential to promote deep integration between digital twin technologies and urban spatial planning theories, and realize seamless docking between technical skills and professional knowledge.

For foundational courses, colleges add introductory content about urban 3D information collection and multi-source data processing related to the digital twin. For core planning courses, teaching content about digital twin modeling, spatial simulation and scheme optimization is incorporated. For practical courses, teaching is linked with real digital twin planning projects to realize technical applications in real scenarios. Meanwhile, outdated qualitative analysis content in traditional courses is simplified, while content related to data-driven planning and intelligent simulation is strengthened. Updating course content in this way keeps teaching pace with industrial technological iteration and realizes thorough integration of digital technologies and planning theories.

4.3. Interdisciplinary teaching team as talent support

Interdisciplinary teacher collaboration provides reliable human resources for sustainable curriculum integration. Colleges can set up mixed teaching teams composed of planning teachers, digital technology instructors and enterprise engineers, to make up for the deficiency that individual teachers cannot undertake interdisciplinary teaching independently.

Planning teachers are responsible for delivering professional theories, digital technology teachers explain technical principles of digital twin, and enterprise engineers guide practical project training. The three types of teachers cooperate in lesson preparation and classroom teaching, so as to realize synchronous progress of theoretical teaching, technical training and practical exercises. Regular professional training is arranged to improve the digital operation capabilities of planning teachers and supplement planning expertise for technical teachers. Such measures help build composite teaching teams with both professional literacy and technical proficiency, and provide a long-term guarantee for curriculum integration.

4.4. Full-cycle multi-dimensional evaluation for closed-loop management

A sound, full-cycle, multi-dimensional evaluation system serves as the institutional guarantee for effective curriculum integration. Colleges need to establish a diversified assessment mechanism combining process evaluation and result evaluation, on-campus assessment and industrial evaluation, as well as theoretical assessment and technical assessment, to ensure the implementation effect of curriculum reform.

The evaluation team consists of university teachers, digital technology experts and enterprise engineers. Assessment content covers knowledge mastery, technical operation, project implementation and interdisciplinary collaboration capabilities. Evaluation activities run through the whole learning cycle, including pre-class preparation, in-class learning, and after-class practice. Digital twin has greatly changed the teaching mode of landscape and planning majors, and intelligent landscape design based on digital twin is highly interdisciplinary. Therefore, the evaluation system needs to focus on examining students' interdisciplinary application capabilities. The closed-loop assessment mechanism can effectively guarantee the quality of curriculum integration and continuously improve talent training standards [5].

5. Conclusion

The reform of territorial spatial planning and the innovation of digital twin technologies jointly drive the urban spatial planning discipline to carry out in-depth curriculum integration and teaching innovation. In response to new trends

brought by planning system restructuring, technological upgrading and industrial talent demands, this paper constructs a vertical progressive and horizontal interconnected curriculum system. By adopting four major strategies, including virtual-physical integrated teaching, course content restructuring, interdisciplinary teacher cooperation, and full-cycle closed-loop evaluation, the research solves prominent problems such as fragmented course content and separation between digital technologies and professional teaching.

In the future, colleges need to keep track of technological iterations of digital twins and policy updates of territorial spatial planning, and continuously optimize the curriculum integration mode. It is necessary to cultivate interdisciplinary talents equipped with planning literacy, digital skills and rich practical experience, so as to provide sufficient professional talents for smart city construction and intelligent territorial governance.

Disclosure statement

The author declares no conflict of interest.

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