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Course teaching reform of Principles of Urban Planning driven by competition and empowered by intelligence—A case study of digital renovation of wooden houses

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Abstract: Against the backdrop of urban-rural built-stock regeneration and digital transformation, traditional Principles of Urban Planning teaching suffers from theory-practice separation, inadequate engineering training, lagging digital tools and simplistic evaluation. Taking the intelligent construction competition and the wooden house renovation project at Fujian Agriculture and Forestry University as a case, this paper integrates 3D scanning, point cloud modeling, BIM reverse modeling, performance simulation and digital twin into teaching, creating a workflow consisting of project introduction, data acquisition, model construction, problem diagnosis, scheme design, competition defense. It transforms spatial cognition, adaptive renewal, low-carbon decision-making and planning implementation into practical tasks, forming a competition-driven, project-centered, intelligence-assisted, performance-oriented teaching mode. Practice shows it shifts students from rote memorization to problem analysis and from single-scale to multi-scale thinking, improving their digital-modeling, teamwork, decision-making and presentation skills. This approach provides insights for interdisciplinary talent training for urban-rural planning.

Keywords: urban planning; intelligent construction; artificial intelligence; renovation; digital twin

1 Introduction

Urban-rural planning is shifting from incremental expansion to stock renewal, quality upgrading and dynamic governance. AI, information modeling, data computing and digital twin reshape the field, requiring planners to grasp spatial layout, facility allocation, data analysis, performance evaluation and full-lifecycle management.

As the core course for planning majors, Principles of Urban Planning fosters spatial thinking but has three defects. Theory is disconnected from practice: students learn concepts without data training for real spatial problems. Course content lacks connection with engineering practice: it prioritizes land layout and design drawings while ignoring structural safety, building performance and post-occupancy performance. Digital tools are decoupled from theoretical instruction; students struggle to apply 3D scanning, digital twins and simulation in spatial analysis and planning decision-making.

Intelligent construction competitions provide real, assessable projects. The wooden house renovation project at

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Fujian Agriculture and Forestry University tackles leakage, poor insulation, weakened timber bearing capacity and incomplete digital archives through 3D scanning, point cloud processing, reverse modeling, simulation, minimally invasive renovation and digital twins. Covering renewal, heritage conservation and low-carbon management, it acts as a complete practical case. This paper addresses three research questions: transforming competition tasks into teaching content, integrating planning theories into competition practice, and applying digital tools to optimize teaching capabilities.

2 Pain points of traditional courses and reform logic

2.1 From knowledge memorization to problem interpretation

Principles of Urban Planning covers wide-ranging content. Isolated knowledge teaching makes students only memorize concepts. By contrast, competition projects require continuous inquiry into site conditions, problems, causes, solutions and effects [1]. The course reorganizes teachingcontents into six steps: status cognition, problem identification, cause analysis, scheme design, effect evaluation and operation feedback. Taking the wooden house renovation project as a case, students analyze roof leakage, poor wall insulation and reduced timber bearing capacity, linking planning theories, physical space, surroundings and engineering technologies.

2.2 From single-scale analysis to multi-scale collaboration

Traditional teaching focuses on single-scale master plans, regulatory detailed plans and architectural design. This intelligent construction competition demands cross-scale analysis acrossing region, building, component and material. The course thus establishes the framework of "regional environment–block space–individual building–component and material" [2]. It helps students interpret relations among buildings, nature, public space, regional culture and engineering, strengthening multi-scale spatial analysis.

2.3 From outcome evaluation to performance feedback

Traditional assessment prioritizes drawings and texts, ignoring structural safety, energy consumption, comfort and maintenance cost. This course adopts model analysis, structural checking and operations and maintenance simulation to form a "design–simulation–feedback–optimization" loop [3], shifting students' attention away from formal expression to practical scheme performance and overall benefits.

2.4 From competition participation to competition-integrated curriculum

Competition-integrated teaching does not treat competition results as simple coursework. It embeds competition projects, workflows and evaluation criteria into teaching. Its core logic is that competitions provide real problems, courses offer theories, and intelligent technologies support analysis. Competitions serve as practical carriers, planning principles as theoretical bases, and digital technologies as auxiliary tools, integrating theory with real projects.

3 Competition-driven teaching framework for the course

This research establishes the framework of "one main thread, four types of tasks, six stages" [4].

3.1 One main thread: full-process real-engineering problem solving

Focused on safe, low-carbon and adaptive wooden house renewal under urban stock regeneration, the course aligns teaching with competition demands and project practice. Rather than carrying out isolated drawing or software tasks, students complete the full cycle of investigation, analysis, design, evaluation and presentation based on the real building.

3.2 Four types of tasks: comprehensive ability training

(1) Spatial cognition task: Conduct field survey, 3D scanning, data collection, point cloud processing and status archiving to clarify the building's spatial relation with surroundings.

(2) Problem diagnosis task: Detect roof, wall, structural and environmental defects via site investigation, 3D identification and group discussion; analyze contributing factors from geography, climate and functional use to support

scheme formulation.

(3) Scheme decision-making task: Apply urban planning and structural theories to carry out multi-scenario assessment from social, economic, heritage, ecological and construction dimensions, and propose targeted renovation plans.

(4) Comprehensive expression task: Present outcomes and complete defense using digital twin platforms, point cloud reports, solid models and design documents.

3.3 Six stages: linking competition and teaching

Combining AI-assisted literature review and competition scenarios, this teaching approach forms a six-stage closed loop: project introduction, data acquisition, model construction, spatial diagnosis, scheme design and competition defense. It integrates theories, digital operation and competition practice, improving students' capacity to identify, analyze and solve spatial problems.

4 Correspondence between course content and competition tasks

Table 1. Correspondence between course content and competition tasks

Course Knowledge Module	Competition Practice Task	Digital and AI Tools	Ability Objective
urban and rural spatial system	analyze the relationship between buildings and the surrounding environment, transportation and public space	GIS, point cloud browsing, intelligent retrieval	systematic cognition ability
urban and rural planning survey	site reconnaissance, image recording, 3D scanning and problem archiving	3D laser scanning	investigation and data acquisition ability
urban and rural spatial form	reverse restoration of architectural form and spatial structure	point cloud processing, BIM modeling	spatial modeling ability
human settlement environment and building performance	analyze roof, wall, structural and thermal performance problems	performance simulation, model analysis	problem diagnosis ability
adaptive renewal	propose minimally invasive, low-carbon and style-coordinated renewal schemes	AI-assisted scheme comparison, parametric design	comprehensive decision-making ability
planning implementation and management	build a digital twin operation and maintenance platform	digital twins, IoT simulation	implementation and management ability
planning achievement expression	complete design descriptions, calculation documents and competition defense	AI-assisted typesetting, simulated defense	comprehensive expression ability

This correspondence shows that competition tasks can cover the main teaching content of the course, including spatial cognition, problem analysis, scheme design, implementation management and achievement expression. Digital technology

instruction has also shifted from isolated skill training to the use of professional tools for planning analysis and scheme decision- making.

5 Teaching organization and implementation mechanism

5.1 Establishing a cross-disciplinary collaborative teaching team

The project covers urban-rural planning, architectural design, timber engineering, building physics, digital modeling and project management [5]. Therefore, the course adopts joint teaching: planning teachers from Fujian Agriculture and Forestry University are responsible for spatial logic and teaching arrangement, teachers from the School of Fuzhou University of International Studies and Trade for technical verification, equipment suppliers for guidance on software and hardware, and student teams for project execution and outcome integration.

This collaborative model overcomes the knowledge limits of individual courses and teachers, advancing cross-disciplinary integration of planning, architecture, structure and digital technologies.

5.2 Implementing project-based and group-based teaching

A project team of 3-5 students works in roles including project leader, data acquisition specialist, model builder, scheme designer, performance analyst and achievement presenter. Each member undertakes specific tasks while mastering the overall logic of the project, avoiding the one-sided skill structure of "only proficient in software but ignorant of principles".

The teaching process is divided into six stages around the competition: project introduction, data acquisition, model construction, spatial diagnosis, scheme design and competition defense. Each stage sets phased deliverables and progress reports, and teachers provide timely guidance through technical review, problem lists and group discussions.

5.2.1 Project introduction: establishing the problem context

Teachers guide students to interpret policy documents such as the national 15th Five-Year Plan Carbon Peak Action Plan, the 2030 Development Guide for Housing Quality Improvement Project issued by the Ministry of Housing and Urban-Rural Development, and the Implementation Opinions on High-Quality Promotion of Urban Renewal issued by Fujian Province. Meanwhile, teachers explain the competition task statement in detail, and clarify that the tracking assessment consists of four modules: data acquisition (15%), point cloud modeling (15%), twin scenario (20%) and defense presentation (50%). This reflects high requirements for participating teams in terms of professional reserve, software operation, innovative thinking, academic writing and on-site presentation ability.

Teachers introduce the course with on-site photos, point cloud models and competition task statements of wooden house (Figure 1), and organize discussions on issues such as "preservation or renewal, partial repair or overall renovation, and how to balance architectural style and performance".

Students use artificial intelligence tools to assist with policy review, literature research and case anyalysis, and form preliminary problem hypotheses and investigation plans.

5.2.2 Data acquisition: completing digital archiving

Preparatory work: The team prepares in advance by mastering modeling software, operating the Laijiade L500 3D laser scanner, practicing point cloud processing, testing the low-code digital twin platform, studying cases and interpreting policies. Students learn the operation, functions, key points and principles of relevant hardware and software.

Field investigation: Students examine the site environment and the internal layout of the timber house, recording roof conditions, wall insulation and cracks. They reasonably arrange scanning stations according to site and equipment conditions, operate the L500 scanner (Figure 2), and scan the building's exterior and interior to acquire complete, accurate real-scene data. This session helps students recognize the significance and standardization of field investigation.




Figure 1. On-site wooden house Figure 2. 3D laser scanning

5.2.3 Model construction: realizing spatial information expression

Students process point cloud data for coordinate unification, denoising, registration and texture matching, and model wooden columns, beams, walls and roofs to create a structural model. It supports renovation design for structural defects and poor energy performance, while developing students' awareness of fieldwork norms, data thinking, and on-site judgment.

5.2.4 Spatial diagnosis: analyzing problem causes

Focusing on roof leakage, insufficient wall insulation, poor structural load-bearing capacity, students identify contributing factors: humid climate of southern Fujian, the inherent limitations of timber, and elevator-induced risks such as beam-column deformation, wall cracks and weakened fire evacuation. This analysis supports scheme design and strengthens students'comprehensive problem analysis.

5.2.5 Scheme design: conducting multi-scheme comparison

- Core concepts of the project

Style preservation: 1:1, millimeter-accurate reverse modeling from 3D scanning reconstructs the undocumented wooden house envelope for full-lifecycle digital management. Structural safety: CFRP minimally invasive reinforcement strengthens timber members, retaining original form and improving bearing and seismic capacity. Low-carbon energy saving: Breathable roof insulation and PCM walls boost thermal performance and reduce operational energy and carbon emissions.

- Innovative renewal schemes

The triple-function roof system addresses leakage, mildew and energy waste; PCM walls increase thermal inertia; CFRP reinforcement delivers low-impact, low-carbon structural upgrade. A digital twin platform supports full-lifecycle archiving and operation. AI aids analysis and optimization, yet final decisions require evaluation of building value, cost, regional features and maintenance.

- Digital twin visualization platform

A lightweight low-code digital twin platform enables real-time risk monitoring. It integrates point cloud, energy and sensor data, visualizes internal structures, simulates IoT indicators, generates real-time charts and enables dynamic building management.

5.2.6 Competition defense: completing comprehensive evaluation

Structural and digital-intelligent simulations help students assess renovation performance concerning energy use, structural safety, construction impact, carbon emission and operational efficiency. They adjust structural forms, material thickness and reinforcement parameters to build a "design-simulation-feedback-optimization" loop.

For the defense, students structure presentations around project background, engineering issues, technical workflow,

renovation plans, quantitative outcomes and intelligent operation. They present via reports, 3D models, digital twin scenes, low-code platform interfaces, design files and construction animations. Post-defense reviews examine point cloud processing, regional scheme adaptation and advanced technology use, informing future competitions.

Registration Quality Report

Average Registration RMSE (m) 0.007706

Reference Station	Source Scan Station	Registration RMSE (m)	Overlap (%)
1-1	Fujian Civil Engineering	0.007706	21. 97

Figure. 3 Registration report

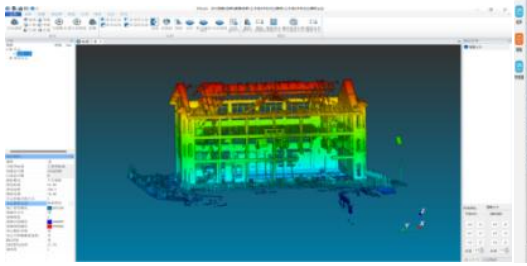


Figure 4. 3D modeling

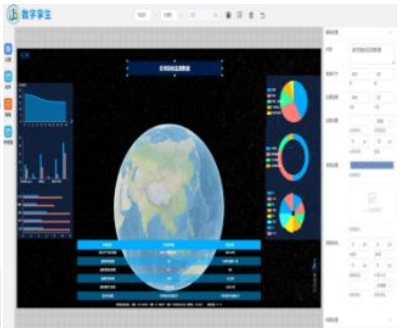


Figure 5. Low-Code platform

6 Reform effects and main characteristics

By taking part in the Fujian Provincial College Students' Intelligent Construction Competition, the team won provincial awards. Students have gained profound growth in personal development, career planning and professional ability, and the discipline construction has also been promoted.

6.1 Promoting the integration of competition into course teaching

In this project, the technical requirements, workflow, depth of deliverables and scoring standards of the competition are fully integrated into course teaching, strengthening the linkage between competition and the curriculum. Students participate in real projects while completing course learning, and gain a more comprehensive and in-depth understanding of relevant knowledge points of Principles of Urban Planning through project practice.

6.2 Strengthening the linkage between theoretical knowledge and real- world scenarios

Through the competition, students form an objective understanding of the feasibility of planning proposals. They realize that the renewal and renovation of wooden houses should not only consider site environment, renewal policies, regional characteristics and spatial layout, but also comprehensively take into account implementation conditions such as structural safety, building performance, construction disturbance and post-construction maintenance.

6.3 Establishing a comprehensive spatial cognitive framework

Through 3D scanning, point cloud processing and modeling, students can establish multi-scale and cross-disciplinary connections between regional environment, block space, architectural form, component nodes and material properties, forming a comprehensive cognition capacity across macro- to- micro and space- to- component scales.

6.4 Enhancing low-carbon resilience awareness

Through intelligent analysis of energy consumption, materials and carbon emissions, students re-establish the principle of minimal intervention and avoiding large-scale demolition and reconstruction. They can evaluate schemes from a whole-life-cycle perspective, and pay attention to the regional style and construction characteristics of wooden buildings.

6.5 Promoting AI from tool use to whole-process support

In this competition, artificial intelligence tools are adopted throughout the whole process from data collation and recognition to model validation, scheme comparison, performance feedback and defense training. It provides strong support for teachers and students in problem diagnosis, framework construction, scheme comparison, planning decision-making and achievement presentation, further ensuring the pertinence and rationality of measures within the scheme.

7 Conclusion

The intelligent construction competition provides realistic practice for Principles of Urban Planning. Taking the wooden house renovation as the carrier, the course transforms competition requirements into teaching tasks and embeds planning theories into data acquisition, modeling, diagnosis, design, performance evaluation and digital operation. It builds a competition-driven, intelligence-enabled project-based teaching model for comprehensive ability training.

This reform reshapes teaching rather than merely adding software sessions: real projects replace virtual assignments, systematic tasks replace fragmented knowledge, performance assessment supplements drawing evaluation, and process review replaces one-off presentation. Future research will enrich knowledge bases, spatial platforms and digital twin resources, strengthen teaching on regional culture, public participation and social value, and shift focus from drawing training to spatial problem-solving and governance capacity.

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Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

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