Construction of a Modular Teaching System for the Building Physics Course under the Guidance of Green Building

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Abstract: *The in-depth development of green buildings has introduced new requirements for the knowledge structure of architecture professionals, and the traditional course model of building physics, which teaches by sub-disciplines based on physical phenomena, struggles to meet the demands of green building design centered on comprehensive performance optimization. To this end, this study aims to construct a modular teaching system for the building physics course under the guidance of green building. The research first analyzes the intrinsic relationship between green building performance goals and the core elements of building physics, pointing out that modern teaching needs to complete a paradigm shift from "element decomposition" to "system integration." On this basis, this study proposes a modular knowledge restructuring strategy based on problem orientation and system integration, and elaborates in detail on the construction logic of core modules such as the integration of thermal environment and energy consumption regulation, as well as the synergy of light, sound environment and spatial quality. Furthermore, this study plans the logical connection of module sequences and the dynamic teaching process, and explores the teaching strategy of deeply embedding performance simulation tools into design tasks. The research also designs a multi-dimensional feedback mechanism covering knowledge, skills, and thinking to drive the self-optimization of the teaching system. This system aims to transform building physics knowledge from isolated calculation and verification into the core competence and thinking framework that drives innovative green building design.*

Keywords: *green building, building physics, modular teaching, teaching system, performance orientation*

Introduction

The evolution of the concept of green building places the precise control of building performance, especially physical environmental performance, at its core, which makes the fundamental role of the discipline of building physics increasingly prominent. However, the traditional building physics course mostly follows its own disciplinary logic and imparts vertical knowledge through independent units such as heat, light, and sound, and a significant gap exists between its teaching content and methods and the multi-objective collaborative optimization and performance-oriented integrated design emphasized by green buildings. This discrepancy leads to students mastering the principles of sub-item calculations but finding it difficult to comprehensively apply them in complex design contexts to solve practical energy-saving, environmental protection, and comfort problems, resulting in a "disconnect" between knowledge transmission and design application. Therefore, a systematic reconstruction of the existing building physics teaching system to meet the needs of green buildings has urgent theoretical necessity and practical significance. This study is committed to responding to this need by constructing a modular teaching system, exploring how to organically integrate building physics knowledge and transform it into the core teaching resources and capacity-building pathways that support green building design and innovation.

1. Analysis of the Intrinsic Relationship between the Concept of Green Building and the Teaching of Building Physics

1.1 The Physical Core Elements in the Performance Goals of Green Buildings

The performance goals of green buildings are essentially an optimization process of energy and material exchange between the building system and the external environment, and this process is highly dependent on the precise control of the physical elements of buildings. The basic principles of thermal engineering, optics, and acoustics covered by the discipline of building physics directly constitute the core determinants of the indoor environmental quality and energy consumption of a building. For example, the heat transfer characteristics of the building envelope directly affect the heating and cooling loads of the building; the effective use of natural lighting and the collaborative design of artificial lighting are related to the balance between visual comfort and lighting energy consumption; and the sound insulation capability of building components against airborne and impact sounds serves as the technical foundation for achieving acoustic environment comfort.

Therefore, the pursuit of goals such as energy conservation, material saving, and indoor environmental health in green buildings is not an abstract concept but is specifically transformed into quantitative requirements for building physical performance parameters. These performance parameters constitute a key bridge connecting the concept of green buildings with specific design methods, material selections, and construction details. The teaching of building physics needs to clearly identify and deepen these core elements, transforming them from isolated technical indicators into systematic constraints and innovation drivers throughout the entire design process, so that physical performance analysis becomes the fundamental technical approach to achieving green building goals rather than a post-evaluation tool.

1.2 Analysis of the Differences between Traditional Building Physics Teaching Content and the Needs of Green Buildings

The traditional teaching system of building physics is usually organized linearly according to the principles of physics, using independent knowledge blocks such as heat, light, and sound, and focuses on the mechanism explanation and basic calculation of a single physical phenomenon. Although this model of vertical deepening within the discipline ensures the integrity of the knowledge system, it can easily lead to the fragmentation of various physical environmental factors in the teaching process. The teaching content often lags behind the cutting-edge requirements of green buildings for collaborative optimization of comprehensive performance; for example, it rarely explores in depth the dynamic coupling effect between natural ventilation and thermal inertia, or the comprehensive impact of natural lighting strategies on indoor heat gain and glare control[1].

The root of this difference lies in the divergence of teaching orientations. Traditional teaching takes understanding physical phenomena and mastering standard calculation methods as its core goals, whereas a green building orientation requires starting with the end in mind, reversely integrating and applying multiple physics knowledge from the perspective of overall performance goals. This demands that teaching shifts from "explaining phenomena" to "solving problems" and from "complying with codes" to "optimizing performance." The focus of knowledge transmission needs to move from the compliance calculation of isolated parameters to the cultivation of an integrated mindset that seeks optimal performance solutions under multi-objective and multi-variable constraints, thereby bridging the gap between traditional disciplinary subdivision and the systematic nature of green buildings.

1.3 Theoretical Pathways for the Building Physics Knowledge System to Support Green Building Design

The key to constructing theoretical pathways for the building physics knowledge to support green building design lies in achieving a paradigm shift from "element decomposition" to "system integration." This pathway first requires the reconstruction of building physics knowledge into "knowledge clusters" that serve specific green performance goals, rather than discrete formulas and data. For example, around the goal of "winter heat gain and thermal stability," this pathway can cluster and link knowledge points such as solar radiation calculation, building envelope heat transfer theory, thermal inertia principles, and air tightness design, forming a goal-oriented knowledge unit.

The deeper logic of this theoretical pathway lies in establishing a closed-loop relationship among physical principles, quantitative analysis, design strategies, and performance feedback. The teaching needs to guide students to master how to transform physical principles into analyzable and predictable simulation tools, and to use these tools to iteratively evaluate and optimize design schemes. This means that the building physics course needs to introduce performance-oriented design thinking, enabling students to understand that physical calculation is not only a verification tool but also a driving force for generating design solutions. Through the construction of such a theoretical pathway, building physics knowledge can be organically embedded into the green building design process, becoming the core scientific basis for driving form innovation and technical decision-making.

2. Core Architecture and Content Restructuring of the Modular Teaching System

2.1 Principles for Dividing Modular Knowledge Units Based on Green Performance Orientation

The division of modular knowledge units needs to follow the dual logic derived from the design process and performance goals. The primary principle is problem orientation, which means taking the core physical performance problems faced in the green building design process as the starting point for module construction, such as "low-energy design of the building envelope system" or "passive regulation of the indoor light and thermal environment." Each module should correspond to a clear and comprehensive performance issue rather than a single physical law. Secondly, the module division needs to reflect system integration, extracting and reorganizing knowledge points that are traditionally scattered across different fields such as heat, light, and sound but jointly act on the same performance goal, thereby forming a logically interconnected knowledge set and breaking down the barriers within the discipline[2].

The granularity and boundary setting of modules constitute another key principle. Modules should possess relative independence and completeness, enabling each module to be implemented as an independent teaching unit, while clear interfaces need to be reserved between modules. This interface is reflected in the fact that the output of the previous module serves as the background or condition for the input of the next module; for example, the conclusions of the "solar radiation analysis and building heat gain" module will directly serve as input parameters for the "unsteady-state heat transfer and load calculation of the building envelope" module. The division of modules also needs to be scalable and dynamic, allowing new knowledge points or adjustments of focus to be embedded along with the development of green building evaluation systems and technologies, thereby ensuring the timeliness and cutting-edge nature of the teaching system.

2.2 Integrated Knowledge Construction of the Thermal Environment Module and Building Energy Consumption Regulation

The core of the restructuring of the thermal environment module lies in closely integrating the knowledge system of building thermal processes with the dynamic regulation goals of building life-cycle energy consumption. This module needs to go beyond static heat transfer coefficient calculations and instead construct a complete knowledge chain that extends from outdoor climate parameters and solar radiation analysis, through unsteady-state heat transfer of the building envelope and natural ventilation potential assessment, to ultimately lead to building cooling and heating load prediction and energy consumption simulation. Within this chain, the traditionally separated contents of "building thermal engineering" and "building energy efficiency technology" are integrated, emphasizing the causal relationships and parameter transfers between each link, thereby enabling students to master the holistic analytical ability from physical mechanisms to energy consumption outcomes.

The key to integrated knowledge construction is to achieve a closed loop between design strategies and quantitative evaluation. The teaching needs to guide students to use dynamic simulation tools to conduct rapid iterative comparisons of thermal performance and energy consumption for different building envelope design schemes, shading components, and natural ventilation strategies. This requires the direct transformation of design elements such as material thermophysical properties, construction detail design, and spatial forms into calculable physical model parameters. In this way, thermal engineering knowledge is no longer merely a post-evaluation tool but is transformed into an integrated thinking method that can actively drive design decisions and optimize building forms and construction at the conceptual design stage, truly achieving the integration of the design process and the energy consumption regulation process.

2.3 Collaborative Teaching Design of the Light and Sound Environment Module and Building Spatial Quality

The teaching design of the light and sound environment module focuses on the collaborative improvement of visual and auditory perception quality, which is an important component of the indoor environmental health goals of green buildings. This module needs to abandon the traditional practice of treating daylighting, lighting, and architectural acoustics as isolated topics, and instead explore the interactive effects and collaborative optimization paths of the two in spatial design. For example, window design involves multiple physical variables such as natural lighting, view, noise insulation, and indoor reverberation time simultaneously; the selection of interior surface materials is associated with both the distribution of reflected light and the characteristics of sound wave absorption. The teaching needs to reveal these cross-physical-domain correlation mechanisms, cultivating students' ability to comprehensively weigh and integrate design solutions.

The core of collaborative teaching lies in establishing a multi-physical coupling analysis framework with spatial quality parameters as the common goal. The teaching should introduce performance-based parametric analysis methods, enabling students to simulate indicators such as lighting uniformity, glare index, background noise level, and speech intelligibility under different building forms, window-to-wall ratios, and interior material configurations. Through the parallel evaluation and multi-objective optimization of these performance indicators, the teaching guides students to understand how design decisions create synergies or conflicts between the light and sound environments, and then to seek the optimal balance point. This teaching model transforms the physical knowledge of light and sound from a post-hoc remedial measure into an active design language that shapes spatial experience and quality[3].

3. Implementation Path and Quality Evaluation of the Modular Teaching System

3.1 Logical Connection of Module Sequences and Dynamic Organization of the Teaching Process

The arrangement of the module sequences follows the intrinsic logical relationship in which building design and physical performance analysis drive each other. The teaching process starts with the basic module of "environmental analysis and goal setting," which establishes climate response and performance benchmarks, and then connects to the core module of "passive regulation principles and methods," covering the regulation technologies for environmental factors such as heat, light, and wind. The subsequent teaching sequence then moves to advanced modules such as "active system coordination" and "comprehensive performance simulation and evaluation," forming a progressive knowledge architecture from basic principles to integrated application and from single performance to multi-objective collaboration. This sequence ensures that the output of the previous module constitutes the cognitive foundation and technical prerequisite for the next module, achieving a spiral ascent of knowledge and abilities.

The organization of the teaching process needs to abandon the rigid structure of linear sequencing and instead adopt a dynamic and flexible organizational model oriented toward learning outcomes. Its core lies in constructing a micro-teaching cycle in which theoretical cognition, tool methods, and design application are tightly interlocked and capable of rapid iteration. In the teaching of each core knowledge unit (e.g., dynamic thermal response of the building envelope), theoretical lectures should be immediately followed by hands-on training with corresponding parametric analysis tools or simplified simulation methods. Subsequently, a targeted design task with a limited scope directly related to the theory (e.g., optimizing the window performance for a specific orientation) is assigned, prompting students to immediately apply what they have learned for analysis and decision-making. Based on the common cognitive biases or technical difficulties revealed during the task completion process, the instructor can provide immediate collective feedback or supplementary explanations, thereby enabling the teaching pace and depth to be dynamically adjusted according to the students' cognitive state. This organizational approach transforms the teaching process from one-way instruction into an adaptive learning process driven by two-way feedback, significantly improving the efficiency of knowledge internalization and transfer[4].

3.2 Embedding Strategy of Simulation Analysis and Performance-Oriented Design Tasks

The deep embedding of performance simulation analysis tools is a key transformation strategy for converting the modular knowledge system into practical design capabilities. Its core lies in reconfiguring simulation from a traditional post-hoc verification tool into a core reasoning engine that runs through concept generation in the early design stage, scheme comparison and selection in the middle stage, and detail optimization in the later stage. In design tasks, students are required to use the Thsware Green Building Performance Simulation Software to conduct parametric and visual dynamic tests on the physical performance of their design schemes. For example, in a project exploring the relationship between spatial form and natural ventilation, students need to establish multiple massing models, simulate and analyze indoor airflow organization and wind speed distribution under different opening positions, sizes, and spatial connectivity patterns, and then use the simulation results as a direct basis for adjusting the spatial form. This strategy forces design thinking to be built upon quantifiable and comparable physical evidence, prompting the establishment of a direct and rational causal relationship between formal operations and performance goals.

The setting of design tasks must reinforce the clear orientation of their performance goals and the non-uniqueness of the implementation paths, thereby stimulating students' integrative innovation ability. The task brief should define a series of key performance thresholds (e.g., the number of hours during which indoor illuminance meets the standard, the upper limit of the annual thermal discomfort dissatisfaction rate) as mandatory constraints for the design scheme, but it should avoid specifying specific construction practices or technical systems. This requires students to independently mobilize and integrate the principles and methods from different knowledge modules (e.g., thermal environment, light environment, sound environment) to conduct multi-objective trade-offs and optimizations. Students may explore the combination of high-performance glazing, phase-change materials, and adaptive shading systems to collaboratively resolve the contradiction between daylighting and heat gain; or they may balance acoustic privacy and visual transparency in open spaces through the integrated design of spatial layout and sound-absorbing materials. Through this repeated "design-simulation-evaluation-optimization" iterative cycle, students internalize a systematic working mode in which performance data serve as a feedback loop to drive the continuous evolution of design decisions, thereby achieving a capability leap from static knowledge reception to dynamic problem solving[5].

3.3 Multi-dimensional Feedback of Modular Teaching Effectiveness and System Optimization Mechanism

The evaluation of the effectiveness of the modular teaching system should construct a multi-dimensional and process-oriented feedback system that goes beyond a single summative examination. This system needs to comprehensively assess learning outcomes at three levels: knowledge, skills, and thinking. At the knowledge mastery dimension, the system uses modular formative tests and concept mapping to accurately diagnose students' depth of understanding of core physical principles and their interrelationships. At the skill application dimension, the system relies on the process documents, simulation analysis reports, and final optimization schemes submitted by students in each module's design tasks to evaluate their ability to transform theoretical knowledge into technical operations and tool-use capabilities for solving specific environmental performance problems. At the comprehensive thinking dimension, the system uses cross-module comprehensive design research projects or final defense presentations to focus on examining students' higher-order thinking abilities to systematically integrate knowledge from multiple physical domains, make trade-off judgments, and pursue innovative solutions when facing complex, multi-constraint design problems. The feedback data from these three dimensions together constitute a three-dimensional and refined profile of students' learning outcomes.

Based on the multi-dimensional feedback, a closed-loop system optimization mechanism needs to be constructed. The core of this mechanism lies in periodically conducting a structured analysis of the teaching feedback data to identify the weak links in each module regarding knowledge transmission, skill training, or thinking cultivation. The optimization actions point to the adjustment of specific teaching links, such as revising the proportion of theoretical depth and breadth in a particular module, updating the performance parameters and constraints in design tasks, or introducing a more efficient chain of simulation analysis tools. This mechanism ensures that the modular teaching system itself possesses the ability to self-renew and evolve, continuously responding to the cutting-edge demands of technological development in the green building field and talent cultivation, thereby forming a dynamic and flexible curriculum development ecosystem[6].

Conclusion

This study systematically constructs a modular teaching system for the building physics course with green building performance orientation as its core. The system first establishes a teaching paradigm shifting from fragmented knowledge transmission to integrated problem solving by analyzing the intrinsic relationships. Then, taking the design process and performance goals as dual main lines, this system completes the modular restructuring and content innovation of core knowledge such as thermal engineering, light, and sound, emphasizing the integration of energy consumption regulation and the synergy of spatial quality. At the implementation level, this study proposes a logically progressive module sequence and a dynamic and flexible teaching organization method, and ensures the effective transformation of theory into design capability through the deep integration of simulation analysis tools and performance-oriented design tasks. The supporting multi-dimensional feedback and closed-loop optimization mechanism guarantees the adaptability and forward-looking nature of the teaching system. The construction of this system provides a holistic reform framework for building physics teaching from objectives, content, and methods to evaluation. Future directions for deepening can focus on the wider application of emerging simulation tools and digital platforms, the refined development of cross-module comprehensive design projects, and empirical research that longitudinally tracks the effects of this teaching system on students' design thinking and professional ability cultivation, thereby

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