The practice-driven teaching reform of building physics is aimed at cultivating green building design capability.

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Abstract: *Facing the increasingly intensified demands for sustainable development in the building sector, traditional building physics teaching exhibits structural limitations in cultivating professionals with integrated green building design capabilities. This study aims to explore a practice-driven reform pathway for building physics teaching, with its goal directly targeting the systematic generation of students' green building design capabilities. The research first analyzes the shortcomings of the traditional knowledge transmission model, and then demonstrates the necessity of transforming the teaching paradigm towards “design thinking integrated with performance thinking.” The core of the reform is built upon three pillars: first, restructuring the course content system, emphasizing climate-responsive methodology, the logic of technical strategy integration, and the transformation mechanism from physical principles to design decisions; second, constructing a simulation and iterative cycle design teaching method, deeply embedding environmental performance simulation into the entire process of design generation and optimization; and third, establishing a dynamic evaluation system based on capability development gradients, using process-based evidence to assess the evolution of students' comprehensive capabilities. This study provides a systematic theoretical framework and an operable implementation plan for shifting building physics teaching from isolated knowledge transmission to integrated capability cultivation.*

Keywords: *Building Physics; Teaching Reform; Green Building; Design Capability; Practice-Driven; Performance-Based Design; Iterative Teaching; Capability Evaluation*

Introduction

Currently, architectural education is facing the key challenge of how to effectively respond to the green and sustainable development agenda, and its core lies in cultivating students' complex ability to transform environmental performance goals into creative architectural solutions. However, the existing building physics teaching system mostly adheres to the discipline-based modular transmission of knowledge, and its teaching content, methods, and evaluation mechanisms are significantly disconnected from the dynamic and integrated architectural design process. This disconnection makes it difficult for students to internalize the learned thermal, lighting, acoustic and other physical principles into technical thinking and decision-making tools for active environmentally responsive design, thus constituting a weak link in the professional talent cultivation chain. Therefore, the systematic reform of building physics teaching is not only an inherent requirement for improving the effectiveness of the course itself, but also an urgent need to drive the entire architectural education to adapt to the paradigm shift of green development. The significance of this study lies in moving beyond partial adjustments to teaching tools or content, and in proposing a holistic teaching reform framework with “practice-driven” as its philosophy and “capability generation” as its goal, aiming to bridge the gap between physical knowledge and design practice and to establish a solid pedagogical foundation for cultivating professionals capable of undertaking future green building design tasks.

1. Paradigm Shift in Building Physics Teaching and Green Capability Orientation

1.1 The Knowledge Transmission Model of Traditional Building Physics Teaching and Its Limitations

Traditional building physics teaching has long followed a content transmission model centered on the disciplinary knowledge system, and its teaching structure is usually organized linearly according to independent modules such as thermal engineering, optics, and acoustics. This model emphasizes the one-way explanation of physical principles and calculation methods, instilling relevant knowledge as static conclusions. The teaching process is significantly disconnected from the main design curriculum in architecture, and physical knowledge often lags behind or runs parallel to the design process, failing to effectively intervene in the key stages of scheme generation and decision-making. As a result, students' understanding of physical principles remains at the level of abstract theories and isolated calculations, lacking the cognitive framework and operational ability to transform these principles into proactive design strategies. When confronted with the comprehensive and performance-based requirements of green building design, such students exhibit systematic obstacles in knowledge transfer and application.

1.2 The Composition of Green Building Design Capability and the Repositioning of Teaching Objectives

Green building design capability is essentially a kind of integrated technical thinking ability, and its core lies in the systematic decision-making process of transforming environmental performance goals into specific spatial forms and technical strategies. This capability comprises multiple dimensions: the ability to analyze and respond to regional climatic factors, the ability to use quantitative simulation tools for environmental performance prediction and evaluation, and the comprehensive ability to actively reconcile form, space, materials, and physical environmental performance during the conceptualization and development stages of a design. Based on this understanding, the objectives of building physics teaching need to shift from transmitting discrete knowledge points to cultivating students' mental model for establishing causal relationships among performance goals, design variables, and physical effects in an iterative and simulated process, thereby enabling them to master decision-making methods for actively applying and optimizing the quality of the physical environment within a dynamic design process[1].

1.3 The Theoretical Connotation and Implementation Path of the Practice-Driven Teaching Paradigm

The practice-driven teaching paradigm does not refer to specific operational activities, but rather points to a teaching philosophy with “design thinking integrated with performance thinking” as its core. Its theoretical connotation emphasizes embedding building physics knowledge as the underlying logic and generative rules for design generation and evaluation in real or highly simulated design contexts. The implementation path focuses on restructuring the teaching sequence, advancing the learning of physical analysis tools and methods to be conducted in parallel with the design project, and guiding students through the complete cognitive cycle of “performance goal setting, design prototype generation, simulation feedback analysis, and strategy iteration and optimization.” The key to this path lies in constructing a design teaching environment that provides immediate feedback on physical performance, prompting the internalization of knowledge into students' design intuition and judgment basis through the spiral process of “analysis-synthesis,” and ultimately achieving the integrated generation of physical knowledge and design capability.

2. Reconstruction of the Course Content System Integrating Green Building Literacy

2.1 Methodological Teaching of Climate Response and Environmental Analysis Tools

2.1.1 The Analysis of Climate Data and the Logic of Spatial Translation

This part of the teaching goes beyond the simple identification of parameters such as temperature, humidity, and solar radiation, and focuses on explaining the coupling relationship between their temporal patterns (diurnal and seasonal variations) and spatial impacts (site microclimate and differences in building surfaces). Its core lies in cultivating students' ability to deconstruct meteorological data sequences into tangible driving elements for architectural design. For example, this includes converting prevailing wind direction data into the organizational logic of spatial ventilation paths, or interpreting the sun's trajectory as the morphological generation basis for the refined design of self-shading forms and facade shading components.

2.1.2 Critical Application of Environmental Simulation Tools and Result Interpretation

The teaching emphasis shifts from software operation training to a critical understanding of the physical models and algorithmic assumptions behind digital environmental simulation tools (such as ventilation, simulation, sunlight analysis, and daylighting analysis). Students need to master the applicable scope, accuracy limitations, and the uncertainty of output results for different tools. This aims to enable students to reasonably interpret simulation data and to reversely map and translate quantitative results into qualitative decision-making bases for specific design operations such as adjusting building form, opening interfaces, and material properties, thereby establishing a closed-loop feedback between simulation analysis and design iteration.

2.1.3 The Linkage from Site Climate Analysis to Morphological Generation Strategies

The final stage of the methodological teaching is to achieve the transition from analysis to generation. The teaching content focuses on establishing a series of principled “translation” rules that directly guide climate analysis conclusions toward preliminary morphological operations. For example, the analysis of solar radiation heat is transformed into guiding principles for controlling the form factor, limiting the plan depth, or determining the scale of courtyards; the wind environment analysis is directed toward strategic choices for building layout orientation, section design of ventilation cavities, or the optimization of opening positions. This process aims to help students develop a proactive thinking mode that conceives architectural forms based on environmental performance.

2.2 The Integration Logic of Technical Strategies Guided by Performance-Based Design

2.2.1 The Hierarchy and Synergy of Technical Strategies under the Passive First Principle

The teaching first establishes the core priority of passive technical strategies. The content systematically explains how to hierarchically rank and combine basic strategies such as natural ventilation, daylight utilization, envelope insulation, and thermal mass application according to climatic characteristics. The analysis focuses on the synergistic effects among strategies, such as how the coupling of high-transmittance envelopes with controllable external shading, or thermal mass materials with night ventilation, can achieve dynamic thermal comfort; meanwhile, the teaching also reveals potential conflicts, such as the trade-off between the benefits of large openings for daylighting and winter heat gain and the risks of summer overheating and glare, thereby cultivating students' thinking framework for systematically configuring technical measures.

2.2.2 Performance Coupling and Trade-off Analysis in Building System Integration

The teaching content delves into the performance coupling interfaces among various building subsystems (envelope, spatial layout, and rudimentary concepts of equipment systems). For example, the analysis examines how a double-skin facade or an atrium space can simultaneously serve as a thermal buffer layer, a light well, and a ventilation channel, thereby achieving the integration of multiple environmental regulation functions. At the same time, the teaching guides students to conduct critical performance trade-off analyses, such as assessing the accompanying changes in thermal loads when pursuing optimal daylighting, or considering the potential constraints on natural ventilation when optimizing the insulation performance of the envelope. This instruction aims to cultivate students' ability to understand and manage the complex interactions among technical systems[2].

2.2.3 Parametric Expression of Technical Strategies and the Awareness of Performance Optimization

To align with the iterative nature of the design process, the teaching introduces the concept of parametric expression of technical strategies. It transforms technical choices (such as window types, shading depth, and wall construction) and their key attributes into adjustable design variables. Students need to learn how to understand the sensitivity of these variables and their nonlinear impact on overall performance under the constraints of set environmental performance goals (such as total energy consumption and daylight uniformity), thereby establishing a systematic thinking method for seeking performance optimization by adjusting multi-variable combinations.

2.3 The Construction of the Transformation Mechanism from Physical Principles to Design Decisions

2.3.1 The Refinement and Formal Expression of Design Rules

One of the core activities of the teaching is to guide students in refining simple design rules or heuristic principles from the basic principles of thermal engineering, optics, and acoustics that can directly guide spatial and morphological operations. For example, the teaching transforms the principle of steady-state heat transfer into a spatial continuity rule regarding interface compactness and thermal bridge control; it converts the geometric relationship of sunlight into a proportional rule for controlling building spacing and eave overhang depth; and it translates the principle of reverberation time into an initial relational formula concerning spatial volume and the configuration of interface materials. These rules, expressed in formalized language, become tools for rapid decision-making in the early stages of design.

2.3.2 Cross-Scale Knowledge Integration and Embedding into the Design Process

The transformation mechanism emphasizes the integration and application of physical knowledge across different design scales (urban, building, and component). The teaching needs to demonstrate how knowledge of urban-scale wind and thermal environments is applied to the layout of building clusters, how building-scale heat gain and loss analysis is deepened into the design of envelope construction details, and how component-scale optical properties of materials are linked to indoor light environment quality. By systematically embedding these key points of physical knowledge at different scales into the standard design process from conceptualization to detailed development in a forward-looking manner, the teaching enables students to clarify the core physical issues that should be addressed and utilized at each design stage.

2.3.3 Dynamic Feedback and Decision Optimization in the Iterative Cycle

The ultimate transformation mechanism is embodied in a dynamic feedback loop that integrates “ prediction, simulation, evaluation, and adjustment. ” Through design exercises, the teaching constructs a virtual design experiment environment where students can obtain immediate feedback on environmental performance. In this environment, students generate schemes based on initial rules, use analytical tools to obtain performance data, interpret the design semantics behind the data, and then make targeted adjustments to form, space, or technical parameters. Through multiple iterations, students not only verify physical principles but also deeply experience how subtle design decisions affect performance outcomes, thereby solidifying physical thinking into an instinctive response for continuous optimization decisions throughout the entire design process.

3. Teaching Process and Evaluation System for Design Capability Generation

3.1 The Design Process Teaching Method of Simulation and Iterative Cycle

3.1.1 The Forward Placement of Performance Goals and the Driving Intervention in Preliminary Morphogenesis

The teaching begins with the setting of the performance goal framework for the design task, guiding students to transform abstract green concepts into specific, quantifiable, and phased performance indicators. Under this framework, students are required to use simple climate analysis tools and morphological generation rules for conceptual design, achieving early-stage constraints and driving forces on basic morphological parameters such as massing, layout, and orientation through performance goals. This stage emphasizes the logic of “ analysis as generation. ” For example, the teaching directly transforms solar path analysis into geometric operations for self-shading forms, or interprets the site wind rose diagram as the spatial topology of planar ventilation paths, making environmental response the initial logic of morphogenesis rather than a post-hoc correction.

3.1.2 The Deepening Design and Dynamic Adjustment under Multi-Parameter Interaction

As the scheme progresses, the teaching introduces more precise simulation tools to construct a design experiment field with multi-variable interaction. Students need to operate a set of interrelated design variables, such as window-to-wall ratio, the depth of shading components, and the thermal performance of the envelope, and observe their coupled effects on multiple performance indicators including daylighting, heat gain, and energy consumption. The teaching process focuses on training students to identify key performance-sensitive parameters and to understand the trade-off relationships among variables, such as the contradiction between the benefit of increased window area for natural daylighting and its potential impact on cooling loads. Through multiple adjustments based on simulation feedback, students master the design decision-making method of seeking the system optimization point in a dynamic balance.

3.1.3 Integrated Simulation and Collaborative Optimization of Comprehensive Performance

In the advanced stage of the teaching, the teaching guides students to use an integrated environmental performance simulation platform to conduct coupled simulation evaluations of multiple physical fields, including energy consumption, sunlight, natural lighting, and ventilation, for their design schemes. The focus lies in interpreting comprehensive performance reports, identifying interactions and potential conflicts among different subsystems, and then performing high-level collaborative optimization based on these findings. For example, the teaching involves adjusting the atrium design to simultaneously improve natural ventilation and daylight distribution, or optimizing the envelope construction to balance insulation, thermal resistance, and light transmission requirements. This process aims to cultivate students' top-level design thinking ability to manage complex systems and achieve overall performance enhancement.

3.2 The Cultivation of Comprehensive Capability Combining Quantitative Analysis and Qualitative Judgment

3.2.1 The Ability to Accurately Obtain and Critically Interpret Quantitative Data

The primary goal of the teaching is to ensure that students can proficiently use professional tools to obtain accurate quantitative data on environmental performance and understand the physical meaning and technical boundaries behind such data. More importantly, the teaching aims to cultivate the ability to critically interpret quantitative data, enabling students to identify the assumptions and uncertainties of simulation results, judge the validity of the data, and avoid a mechanical reliance on quantitative outcomes. For example, students should be able to discern the impact of computational grid density on wind speed simulation results, or understand the differences between standard annual meteorological data and actual climate fluctuations[3].

3.2.2 Design Semantic Translation and Multi-Criteria Value Trade-off

The core teaching task lies in training students to “translate” quantitative data into qualitative judgments with design semantics. Faced with the simulation result of an overheated zone, students need to combine spatial function, user behavior, and thermal comfort theory to determine whether this is a problem to be solved by shading, ventilation, or spatial reorganization. By introducing typical conflicting situations, such as the conflict between maximizing natural lighting and controlling summer solar heat gain, or the contradiction between optimizing ventilation efficiency and ensuring spatial acoustic privacy, the teaching guides students to conduct multi-criteria value trade-offs and explore non-unique solutions based on specific contexts and priorities.

3.2.3 Holistic Decision-Making Capability Based on the Concept of “Appropriate Performance”

The ultimate goal is to cultivate a holistic decision-making capability that is built upon technical rationality and integrates considerations of humanity, economy, and user experience. The teaching guides students to establish the concept of “appropriate performance,” understanding that green building is not about the extreme optimization of each indicator, but rather the most suitable balance under specific constraints. Students need to learn to comprehensively consider technical solutions, construction costs, spatial quality, operation and maintenance, as well as users' perceptual experience, and to make comprehensive design judgments that are both scientifically sound and practically feasible, thereby completing the role elevation from a technical analyst to a design decision-maker.

3.3 A Dynamic Teaching Evaluation Mechanism Based on Capability Development Gradients

3.3.1 The Deconstruction of Capability Dimensions and the Modeling of Development Ladders

The foundation of the evaluation system lies in the operational deconstruction of “green building design capability,” forming a clear matrix of capability dimensions, such as environmental analysis, tool application, strategy generation, iterative optimization, and comprehensive decision-making. For each dimension, the system constructs a progressive capability development ladder model from “awareness,” “understanding,” and “application” to “innovation,” and describes the specific behavioral indicators for each rung. This model provides a common and objective reference framework for teaching and evaluation, making capability development visible and measurable.

3.3.2 Process-Oriented Evidence Collection and Embedded Formative Evaluation

The evaluation activities are deeply embedded into the iterative cycle of teaching, emphasizing the continuous collection of process-oriented evidence. Such evidence includes process-based outputs such as sketches, models, simulation analysis reports, design decision logs, and group discussion records at each iteration stage. Through regular reviews and targeted feedback, the instructors conduct embedded formative evaluations on student performance, focusing on the rigor of their analytical logic, the consistency of their strategy evolution, and their initiative in learning and adjusting from feedback. This evaluation method directly responds to the characteristic of design capability being generated through the process.

3.3.3 Summative and Developmental Evaluation Focusing on Capability Evolution Trajectories

The final summative evaluation not only focuses on the static performance of the design outcomes, but more critically, it retrospectively examines and assesses the student's capability evolution trajectory across the entire learning cycle based on process-oriented evidence. The evaluation report clearly indicates the development ladder reached by the student in each capability dimension, analyzes the progress of their thinking patterns and the bottlenecks yet to be overcome. The essence of this evaluation is developmental, aiming to provide students with personalized capability diagnosis and a development roadmap, thereby making the evaluation results a catalyst for their subsequent professional growth and closing the loop of the overall teaching reform objectives.

Conclusion

This study has systematically constructed a practice-driven teaching reform framework for building physics, which aims to cultivate green building design capability. By facilitating the paradigm shift of teaching from knowledge transmission to capability generation, this framework realizes the logical restructuring of the course content system from isolated knowledge points to an integrated methodology, and develops a closed-loop teaching process centered on simulation and iteration that integrates quantitative and qualitative judgments. The supporting dynamic evaluation mechanism extends the focus from final outcomes to the entire trajectory of the capability development process.

Reform practice shows that this pathway effectively guides students to establish causal thinking among performance goals, design variables, and physical effects, elevating environmental response from a verification step in the later stage of design to a driving force for morphogenesis and scheme optimization. Future directions for deepening the teaching can focus on broader interdisciplinary knowledge integration, explore the forward-looking application of artificial intelligence-assisted performance prediction and generative design in teaching, and continuously improve learning analytics based on big data, so as to construct more precise and personalized capability development and evaluation models, thereby advancing building physics education towards higher levels of adaptability, intelligence, and creativity.

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