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Modeling of Pedagogical Technology in Teaching Organizational and Technological Design of Low-Rise Residential Buildings

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ABSTRACT

This article presents a scientific and methodological model of pedagogical technology for teaching organizational and technological design of low-rise residential buildings. The study responds to the need to connect construction-process planning, rational fuel-and-energy resource consumption, digital modelling and Competency-Based assessment in architectural education. The methodology is based on design-based pedagogical modelling, analysis of construction-sector indicators of Uzbekistan, published energy-efficiency evidence and the transformation of professional actions into learning tasks. The proposed model includes four interconnected blocks: construction-context diagnosis, digital organizational-technological modelling, energy and process optimization, and reflective competency assessment. Real secondary data show that completed construction works in Uzbekistan reached 91,621.5 billion UZS in January-May 2025, while buildings and structures accounted for 68.4% of the total construction volume. These indicators justify the use of real project cases in teaching low-rise residential design. The results demonstrate that students can develop project-based thinking when they compare alternative technological solutions through measurable schedule, resource, energy and quality indicators. The model may be applied in architecture, construction engineering and applied technical qualification programmes.

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Introduction

Organizational and technological design is one of the most practice-oriented components of construction education. In low-rise residential construction, students must understand not only the architectural layout of a building but also the sequence of construction processes, the choice of mechanisms, the duration of operations, the organization of the construction site and the consumption of fuel and energy resources at different stages of work [1,2]. Therefore, this subject cannot be effectively taught only through theoretical lectures or isolated calculation exercises.

The relevance of the topic is strengthened by the current dynamics of the construction sector in Uzbekistan. According to official statistics for January-May 2025, completed construction works amounted to 91,621.5 billion UZS and reached 110.0% compared with the corresponding period of the previous year [3]. The construction of buildings and structures formed the largest activity group, equal to 62,700.8 billion UZS or 68.4% of the total volume. Such figures show that design decisions made in the educational process must be linked with real production conditions and economic indicators.

A second argument is connected with rational energy consumption. Low-rise buildings are often considered cheaper and technologically simpler than high-rise buildings, but their construction still requires electricity, fuel, mechanized equipment, temporary site infrastructure and transport resources. Moreover, decisions made at the design stage influence both construction energy consumption and the future operational energy performance of residential buildings [4,5].

Digital technologies create methodological conditions for a new approach. Building Information Modelling (BIM), 4D scheduling, resource mapping and project-based learning allow students to see a construction project as an integrated system. In this system, design, technology, schedule, resources, safety, quality and energy efficiency are not separate topics but interdependent components of one decision [6,7].

The aim of this article is to model a pedagogical technology for teaching organizational and technological design of low-rise residential buildings by integrating real sectoral evidence, BIM-based project work, rational energy consumption and Competency-Based assessment. The research tasks are to define the structure of the pedagogical model, select real data for educational cases, formulate measurable learning products and develop a rubric for evaluating student performance.

Methodology

The study follows a design-based research logic. The initial problem field was formed from a topic manuscript on the modelling of pedagogical technologies in teaching organizational and technological design of low-rise residential buildings. The manuscript emphasizes rational energy use, staged organization of construction processes, digital modelling and a Competency-Based approach as the main didactic directions.

The empirical base consists of three groups of sources. The first group includes official construction statistics of Uzbekistan, especially data on completed construction works for January-May 2021-2025 and the 2025 structure of construction works by economic activity. The second group includes published evidence on energy efficiency in buildings and rational consumption of fuel and energy resources. The third group includes scientific literature on BIM education, project-based learning and Competency-Based assessment in professional education.

The pedagogical model was developed through the following procedure: identification of professional actions required in organizational-technological design; transformation of these actions into learning tasks; linking of each task with digital tools and energy-resource indicators; and definition of an assessment rubric. The model is intended for a semester module in architecture, civil engineering, construction technology or applied technical qualification programmes.

Data analysis used descriptive statistics and comparative interpretation. Construction volumes were visualized as time-series indicators; activity shares were recalculated from official volume data; and energy-efficiency evidence was presented as ranges because published sources usually report reduction potentials rather than one universal value. The educational result is therefore presented not as fabricated classroom scores but as a transparent, evidence-based pedagogical design that can be validated in future teaching experiments.

Table 1: Research Design and Evidence Base

Component	Operational Meaning in this Article	Evidence / Output
Object of study	Teaching organizational-technological design of low-rise residential buildings	Pedagogical technology model
Subject of study	Integration of BIM, staged construction, resource-energy analysis and competency assessment	Four-block didactic cycle
Empirical data	Official construction statistics and published energy-efficiency evidence	Figures 2-4 and Tables 3-5
Analytical method	Design-based modelling, descriptive statistics and competency mapping	Pedagogical algorithm and rubric
Expected use	University module for architecture and construction students	Project portfolio, variant comparison and reflective defense

Source: Developed by the Author Based on the Topic Manuscript and Published Construction/Energy-Efficiency Evidence.

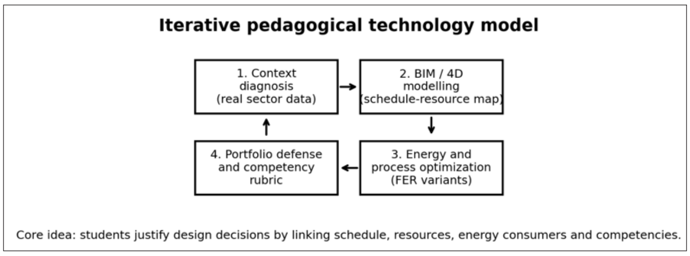

Figure 1: Iterative Pedagogical Technology Model for Teaching Organizational-Technological Design

Source: Author's Model.

Results and Discussion

Pedagogical Technology Model

The proposed technology is built as an iterative learning cycle rather than a sequence of isolated lectures. The student starts from a real sector problem, creates a digital and organizational-technological representation of the project, calculates resource and energy indicators, compares alternatives and defends the selected solution. This approach corresponds to the logic of professional project work, where every technological decision must be justified by evidence.

The model shown in Figure 1 is cyclical. If the selected technology causes excessive energy consumption, schedule risk or poor resource balance, students return to the digital organizational-technological model and adjust the sequence of works, equipment choice, temporary infrastructure or material logistics. Thus, mistakes become part of the learning process, and the teacher evaluates not only the final drawing but also the student's reasoning trajectory.

Table 2: Structure of the Proposed Pedagogical Technology

Block	Teacher activity	Student activity	Measurable learning product
1. Construction-context diagnosis	Provides official statistics, project brief and design constraints	Identifies building type, site conditions, organizational risks and energy consumers	Problem passport and initial resource list
2. Digital OTD modelling	Demonstrates BIM/4D logic and schedule-resource links	Builds a schematic BIM or 4D model, work breakdown structure and calendar plan	Digital model, work sequence and resource schedule
3. Energy and process optimization	Guides calculation of FER indicators and alternative variants	Compares equipment, temporary facilities, transport and envelope decisions	Variant comparison table and energy-resource matrix
4. Reflection and assessment	Organizes peer review and portfolio defense	Explains the selected solution, limitations and expected construction effect	Final portfolio and competency score

Source: Author's Pedagogical Model.

Sectoral Evidence for Content Selection

A professional pedagogical model must be grounded in the actual structure of the construction sector. Official data show that completed construction works in Uzbekistan increased strongly after 2023 and reached 91,621.5 billion UZS in January-May 2025. This creates a strong argument for using real national data in classroom assignments, because students can connect abstract design problems with measurable sectoral demand and regional development.

The dominance of building and structure construction supports the focus on low-rise residential buildings. Although the statistical category also includes other buildings, it is the closest macro-level indicator for the professional field where future architects and construction engineers will work. In a classroom case, these data can be used to ask students why low-rise housing requires reliable scheduling, rational technology selection and standardized documentation.

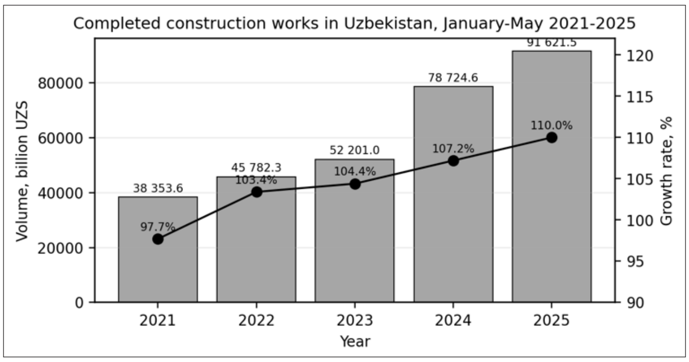

Figure 2: Completed Construction Works in Uzbekistan, January-May 2021-2025

Source: Compiled from the National Statistics Committee Press Release on Construction Works for January-May 2025.

Table 3: Main Official Construction Indicators Used in the Educational Case

Indicator	2025 value	Interpretation for teaching
Completed construction works, January-May	91,621.5 billion UZS; 110.0% to 2024	Students work with a growing sector where planning decisions have economic weight
Construction of buildings and structures	62,700.8 billion UZS; 68.4% share; 104.3% growth	The core case is linked to the largest construction activity category
Construction of civil facilities	18,948.7 billion UZS; 20.7% share; 121.4% growth	Comparison helps distinguish building projects from infrastructure projects
Specialized construction works	9,972.0 billion UZS; 10.9% share; 130.3% growth	Students include specialized works in the technological sequence
Small enterprises and microfirms	46,905.2 billion UZS; 51.2% of total work	Teaching should develop adaptable and resource-conscious solutions
Informal sector	22,802.0 billion UZS; 24.9% of total work	The course should stress standardization, documentation and quality control

Source: National Statistics Committee of the Republic of Uzbekistan, January-May 2025 Construction Works Press Release.

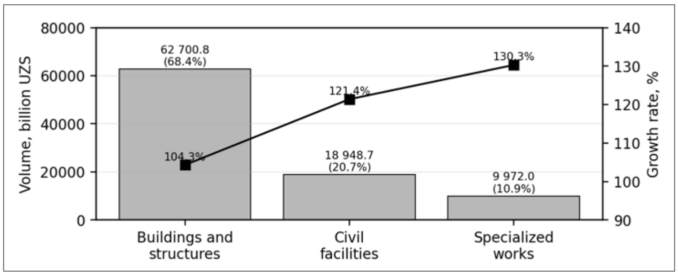

Figure 3: Construction Works by Economic Activity, January-May 2025

Source: Compiled from the National Statistics Committee, January-May 2025.

Energy-Efficiency Evidence and Learning Tasks

The energy component of the model is not an optional ecological addition. It is a professional requirement because design and construction decisions affect the energy consumption of buildings and construction processes. Published energy-efficiency evidence shows that properly selected measures can reduce energy use in buildings substantially; therefore, students should learn to treat energy indicators as part of the technological decision.

For teaching organizational-technological design, energy evidence is transformed into practical learning tasks. Students identify energy consumers during construction: mobile cranes, concrete mixers, welding equipment, lighting, temporary heating, pumping, transport and site offices. They then relate these consumers to design decisions such as wall insulation, window type, roof protection, thermal bridges and renewable energy elements. The result is a combined construction-and-operation view of rational energy use.

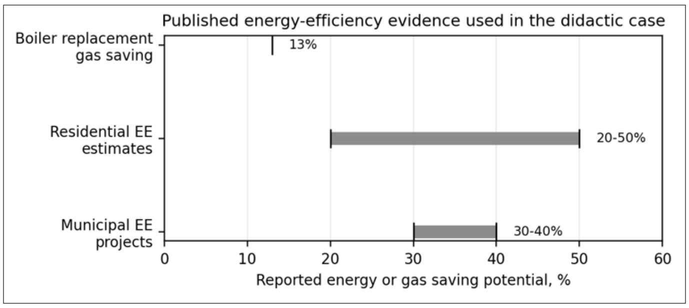

Figure 4: Published Energy-Efficiency Evidence Used in the Didactic Case

Source: Compiled from World Bank and UNDP Evidence on Building Energy Efficiency.

Table 4: Energy-Resource Indicators for a Low-Rise Residential Building Design Task

Indicator group	Student calculation / observation	Pedagogical meaning
Construction machinery energy	Machine-hours by work type; fuel or electricity per machine-hour	Links technological sequence with FER consumption
Temporary site infrastructure	Lighting, heating, water pumping, site office power and temporary networks	Shows that site organization influences energy demand
Material and transport logistics	Transport distance, delivery frequency, storage losses and handling operations	Connects organizational planning with indirect energy use
Building-envelope decisions	Insulation, window type, roof protection and thermal bridges	Connects construction technology with future operational energy
Variant comparison	Baseline, improved technology and energy-efficient design package	Develops decision-making based on measurable alternatives

Source: Author's Transformation of Published Energy-Efficiency Evidence into Educational Indicators.

Competency Assessment and Discussion

Table 5: Competency Rubric for Assessing Student Performance

Competency	Basic level	Satisfactory level	Advanced level
Analytical diagnosis	Lists project conditions without explaining constraints	Explains main site, technology and resource constraints	Connects constraints with schedule, cost and energy implications
Digital modelling	Creates separate drawings or model elements	Builds a coordinated model and schedule-resource structure	Uses the model to compare alternatives and justify changes
Energy-resource evaluation	Identifies some energy consumers	Calculates main fuel/electricity indicators for selected operations	Compares variants and explains energy-saving logic with evidence
Organizational-technological decision	Selects a solution without strong justification	Chooses a feasible solution using schedule and resource data	Defends an optimized solution balancing time, resources, energy and quality
Communication and reflection	Presents results descriptively	Explains calculations and answers questions	Critically reflects on limitations, risks and opportunities

Source: Developed by the Author for Competency-Based Assessment of Organizational-Technological Design.

The final result of the pedagogical technology is not only a completed drawing or schedule. The educational effect must be measured by competencies that correspond to professional actions. A student who creates a visually attractive BIM model but cannot justify the choice of construction sequence, mechanism or energy-saving measure should not receive the same assessment as a student who can defend an integrated organizational-technological solution.

The results indicate that a modern course on organizational-technological design should be organized around real problems, not around isolated definitions. Uzbekistan's construction sector is growing, and buildings and structures form the dominant activity category. At the same time, energy-efficient design and construction are becoming part of policy and development practice. These factors require a teaching model in which students work with real data, compare alternatives and defend decisions under resource constraints.

The proposed model has several advantages. First, it makes the curriculum evidence-based because students use official statistics and published energy-efficiency evidence. Second, it strengthens interdisciplinarity because construction technology, scheduling, building physics, quality control and digital modelling are treated as parts of one solution. Third, it supports Competency-Based assessment because the teacher can evaluate observable outputs at each stage of work.

Implementation also requires methodological discipline. Teachers must prepare project briefs that are neither too simple nor overloaded with unnecessary data. Students need preliminary skills in reading drawings, construction processes, basic energy calculations and digital modelling. The present article therefore presents a structured model and secondary-data evidence base; classroom effectiveness should be verified later through pre-test/post-test diagnostics, portfolio evaluation and student feedback.

In conclusion, the article developed a pedagogical technology model for teaching organizational and technological design of low-rise residential buildings. The main scientific and methodological result is a four-block iterative cycle consisting of construction-context diagnosis, digital organizational-technological modelling, energy and process optimization, and reflective competency assessment. The model can be used as a semester project, practical module or laboratory-practical cycle in architecture and construction curricula [8-12].

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