


## METHODOLOGICAL FOUNDATIONS FOR IMPROVING THE TEACHING OF PHYSICS BASED ON THE INTEGRATION OF ARCHITECTURE AND CONSTRUCTION

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### ANNOTATION

The article analyzes the fundamental physical concepts that enable the integration of physics with general engineering sciences in technical higher education institutions. It discusses the essential links between physics and engineering disciplines and highlights their practical significance. The study also clarifies the objectives of teaching architectural and construction sciences, proposes enhanced thematic areas that facilitate the incorporation of physics into engineering curricula, and examines the process of developing professional competence in future construction engineers.

**Key words:** *general engineering sciences, construction engineering, architecture and construction, physics, integration, technical higher educational institutions, specialist, construction, professional competence.*

## FIZIKANI ARXITEKTURA VA QURILISH FANLARIGA INTEGRATSIYASI ASOSIDA O‘QITISHNI TAKOMILLASHTIRISHNING METODIK ASOSLARI

### ANNOTATSIYA

Maqolada texnika oliy ta‘lim muassasalarida fizika fani va umummuhandislik fanlarining integratsiyasini ta‘minlovchi asosiy fizik tushunchalar, fizika va umummuhandislik fanlari o‘rtasidagi fundamental bog‘liqlik hamda uning amaliy ahamiyati tahlil qilinadi. Shuningdek, arxitektura va qurilish fanlarini o‘qitishdan ko‘zlangan maqsadlar yoritiladi, fizikani umummuhandislik fanlariga integratsiyalash imkonini beruvchi takomillashtirilgan mavzular taklif etiladi va bo‘lajak quruvchi-muhandislarning kasbiy kompetensiyasini shakllantirish jarayoni ilmiy jihatdan o‘rganiladi.

**Kalit so‘zlar:** *umummuhandislik fanlari, quruvchi-muhandis, arxitektura va qurilish sohalari, fizika fani, integratsiya, texnika oliy ta‘lim muassasalari, mutaxassis, konstruksiya, kasbiy kompetensiya.*

## МЕТОДИЧЕСКИЕ ОСНОВЫ СОВЕРШЕНСТВОВАНИЯ ПРЕПОДАВАНИЯ ФИЗИКИ НА ОСНОВЕ ИНТЕГРАЦИИ С АРХИТЕКТУРОЙ И СТРОИТЕЛЬСТВОМ

### АННОТАЦИЯ

В статье исследуются базовые физические понятия, обеспечивающие интеграцию физики с общеинженерными дисциплинами в технических вузах. Анализируется фундаментальная взаимосвязь между физикой и общеинженерными науками, а также ее практическая значимость. Определяется цель преподавания архитектурно-строительных дисциплин, предлагаются усовершенствованные тематические направления, способствующие интеграции физики в общеинженерную подготовку, и рассматривается процесс формирования профессиональной компетентности у будущих инженеров-строителей.

**Ключевые слова:** *общеинженерные науки, инженерно-строительная, архитектурно-строительная отрасли, физика, интеграция, технические высшие образовательные учреждения, специалист, конструкция, профессиональная компетенция.*

The introduction of the credit-modular system in training specialists in architecture and construction at technical universities has resulted in an average allocation of 4 to 10 credits for physics. A key feature of this system is the considerable reduction in classroom hours and the sharp increase in the proportion of time designated for independent study. Practical analysis shows that the number of classroom hours has decreased by an average factor of 1.6 compared with the previous system [1].

This situation sets an urgent pedagogical task: ensuring the effective delivery of a large volume of fundamental knowledge within a limited number of classroom hours.

In our view, the most appropriate and scientifically grounded solution lies in the proper organization of classroom instruction and independent learning. In this process, it is essential to consider the future professional orientation of students—namely, their training as civil engineers. Thus, by designing physics instruction on the basis of interdisciplinary integration while maintaining the integrity of its content [2]:

Students' independent work becomes enriched with professionally relevant material.

Classroom time is optimized, and the practical significance of knowledge increases through systematic links between core physical concepts and general engineering disciplines.

Consequently, students can develop a high level of professional competence within a relatively short period of time. International experience demonstrates that the formation of professional competence in future specialists in technology requires the development of several critical quality indicators [3,4]:

- professional motivation;
- inventive and managerial abilities;
- skills in searching for and processing information;
- self-activation and self-development.

The effective use of the didactic potential of intellectual information resources plays a central role in fostering these qualities. In this context, the following methodological approaches are of particular importance for developing the competencies of future engineers engaged in design, production, and organizational-managerial activities in technical higher education institutions [5]:

Systematic implementation of interdisciplinary integration in the educational process. Development of teaching technologies based on software-supported tools for independent learning. Expansion of the didactic possibilities inherent in the educational process. Together, these approaches form the foundation for improving the quality of engineering education and for training highly qualified specialists capable of meeting the demands of the modern labor market.

The contemporary labor market imposes stringent requirements on educational quality, leading to growing competition among graduates. Consequently, the primary task of engineering education is to cultivate professional competence in future specialists, which directly contributes to the effectiveness and quality of their professional activity.

The formation of such a highly qualified specialist is grounded in a competency-based approach, which ensures that educational content corresponds to the requirements of professional competence.

To achieve strategic goals in developing students' professional competence through interdisciplinary integration, university faculty must implement this work systematically. This requires the incorporation of the following organizational mechanisms into curricula [6]:

Planning the organic interconnection (synchronization) of lecture content across departments and disciplines. Establishing strong interdisciplinary “bridges” that link related areas of knowledge.

These systematic organizational measures ensure comprehensive, practice-oriented training for students.

State Educational Standards clearly define the professional and general competencies—that is, the required knowledge, skills, and abilities—that graduates must acquire. In accordance with these standards, effective achievement of the intended learning outcomes within the basic professional education programs is possible only through an integrative approach.

Integrative education is therefore of fundamental importance both for forming the professional competence of future specialists and for ensuring their successful professional practice. Integration eliminates the traditional separation between theoretical sciences (such as physics) and applied sciences (such as general engineering), unifying them into a single systemic body of knowledge [7,8].

The key physical concepts and their professional applications, which ensure the effective integration of physics and general engineering sciences in technical universities, constitute the methodological foundation of this study and are presented in *Table 1*.

Table 1. Basic physical concepts ensuring the integration of physics with general engineering sciences.

General Engineering Discipline	Basic Physical Concepts Supporting Integration
Construction Mechanics	Force; torque; moment of inertia; angular momentum; law of conservation of momentum; mechanical stress; deformation; Hooke's law; absolute and relative elongation; potential energy in tension and compression; ultimate strength; Young's modulus.
Building Physics	Temperature; humidity; thermal conductivity; convection and radiation; absolute and relative air humidity; dew point; light rays; radiant energy; luminous flux; fundamentals of acoustics; physical characteristics of sound (wavelength, propagation velocity, frequency, sound pressure, hearing threshold).
Metal Structures	Density of materials; mechanical stress; deformation; absolute and relative elongation; ultimate strength; stress-strain diagram; Young's modulus; Hooke's law; force; Newton's laws of motion.
Seismic Resistance of Buildings and Structures	Mechanical waves; longitudinal and transverse waves; wavelength; strength limits; vibrations; amplitude; frequency; oscillation period; resonance phenomenon.

The fundamental relationship between physics and general engineering sciences, as well as its practical significance, is presented in Table 2.

Table 2. Fundamental connections between physics and general engineering sciences and their practical significance.

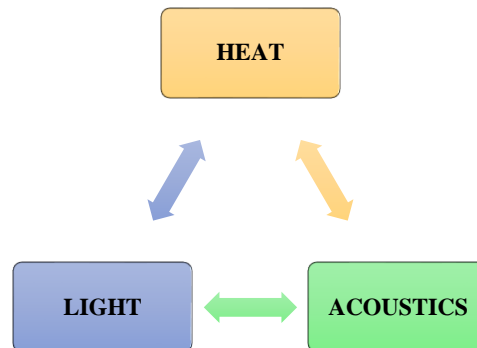
General Engineering Discipline	Fundamental Physical Basis	Practical Significance
Construction Mechanics and Strength of Materials	Mechanics (statics, dynamics, stress, deformation, elasticity).	Calculation of structural strength and stability; ensuring resistance to external loads.
Building Physics	Thermodynamics (heat transfer, thermal conductivity, convection, radiation); Optics (light propagation); Acoustics (sound waves).	Ensuring energy efficiency (thermal insulation), optimal lighting, and sound insulation in buildings.
Hydraulics	Hydrostatics and hydrodynamics (behavior, movement, and pressure of liquids and gases).	Design of water supply, sewerage, heating, and ventilation systems, as well as hydraulic structures.
Seismic Resistance of Buildings	Dynamics (vibrations, oscillations, resonance, propagation of seismic waves).	Development of earthquake-resistant structures and ensuring structural safety during seismic activity.
Building Materials Science	Structure of matter (crystal lattice, phase transitions); physical properties (density, moisture content, thermal conductivity).	Evaluation of material quality and durability; development and optimization of new composite materials.
Power Supply and Electrical Equipment	Electricity and magnetism (electrical circuits, current, voltage, electromagnetic phenomena).	Implementation of building electrification, lighting, automation, and smart building systems.

Students enrolled in architecture and construction programs at technical universities are required to master a wide range of specialized subjects over four years, including Construction Mechanics, Building Materials, Types of Structures (*Wood, Metal, Reinforced Concrete*), Building Physics, and Building Energy Efficiency Engineering. The knowledge and skills acquired in physics provide a fundamental foundation for successful learning in these disciplines. Without an understanding of the fundamental laws and principles of physics, it becomes impossible to scientifically explain or design the physical phenomena and processes – such as deformation, thermal conductivity, and vibration—that occur in buildings and structures [9].

Building Physics and Building Energy Efficiency Engineering examine the physical processes occurring within buildings and their components, as well as the influence of these processes on both structures and occupants. On the one hand, these disciplines address the creation of appropriate indoor temperature and humidity conditions necessary for human comfort and various activities inside the building.

On the other hand, they focus on ensuring conditions that promote the long-term durability and service life of building elements.

The physical processes that take place in a building and its structural components are typically classified into three categories [10,11]:



Thermal engineering examines the transfer of thermal energy within buildings and their components, as well as mass-transfer processes involving water vapor.

Lighting engineering focuses on the formation of natural light fields inside buildings and their influence on human activity. Acoustics studies the laws governing the propagation of sound waves within a building and its individual elements.

A sound understanding of thermal engineering requires mastery of key physical concepts such as the fundamentals of thermodynamics, reversible and irreversible heat processes, the laws of thermodynamics, absolute and relative humidity, and the principles of heat and mass transfer.

To successfully master lighting engineering, students must acquire thorough knowledge of geometric optics, the fundamental laws of optics, and essential photometric concepts and units.

In the study of acoustics, it is necessary for students to understand the propagation of oscillatory motion in elastic media, plane and spherical wave equations, wave interference and diffraction, standing waves, and the properties of sound waves.

For full proficiency in specialized disciplines such as reinforced concrete and masonry structures, metal structures, and timber structures—and for the development of professional competence within these fields students must possess deep knowledge of the following fundamental physical concepts and quantities [12]:

- Physical properties of materials: density, types of deformation, coefficient of linear expansion;
- Mechanical properties: elastic forces, mechanical stresses, absolute and relative elongations;
- Fundamental constant: Young's modulus;
- Strength characteristics: mechanical properties of materials under tension and compression, including ultimate strength.

A thorough mastery of these physical laws and concepts forms the basis for the accurate calculation of load-bearing capacity and the prediction of structural service life in professional practice. Without this foundation, achieving the educational, methodological, and practical learning outcomes required in specialized engineering disciplines becomes impossible [13].

The purpose of teaching key architecture and construction disciplines, as well as the improved topics that promote the integration of physics into general engineering education, are presented in Table 3.

Table 3. Purpose of teaching general engineering disciplines and improved physics-integrated topics for architecture and construction.

No.	General Engineering Discipline	Purpose of Teaching the Subject	Improved Topics Ensuring Integration of Physics into Architecture and Construction
1.	Construction Mechanics	To develop students' knowledge, skills, and abilities in determining stresses and deformations in structural elements, and to teach methods for calculating strength, stiffness, and stability of structures.	Elastic forces; friction-induced failure of building materials; deformational properties of construction materials. <b>Laboratory:</b> Determination of Young's modulus using the bending method.
2.	Fluid and Gas Mechanics	To explain the fundamental principles of fluid and gas mechanics and to apply the basic laws of hydrostatics and hydrodynamics to solve engineering problems involving various types of fluids.	Liquid state of matter; structure of liquids; liquid pressure under curved surfaces; phenomena at the liquid–solid interface. <b>Lecture:</b> Interfacial processes. <b>Laboratory:</b> Determination of the coefficient of internal friction of liquids using the Stokes method.
3.	Seismic Resistance of Buildings and Structures	To equip students with sufficient knowledge, skills, and abilities for calculating buildings and structures under seismic loads and ensuring their earthquake resistance.	Inertial dampers and their use in construction; influence of resonance phenomena on structural behavior. <b>Laboratory:</b> Investigation of the dependence of the speed of sound in air on temperature.
4.	Soil Mechanics, Foundations, and Bases	To provide students with fundamental knowledge of soils and foundations—the key components ensuring the stability and durability of any structure.	Application of Newton's third law in construction; phenomena at the liquid–solid interface; capillarity and its engineering implications.

The key physical concepts that ensure effective integration in technical universities, their equivalents in general engineering disciplines, and the types of professional competence formed on this basis are presented in Table 4.

Table 4. Physical concepts, their engineering equivalents, and the resulting professional competences

Physical Concept	General Engineering Discipline	Engineering Term	Formed Professional Competence
Mechanical stress, deformation, Young's modulus	Strength of Materials	Allowable stress, ultimate strength	Assessment of the load-bearing capacity of materials and structural elements
Thermal conductivity	Construction Thermal Physics	Thermal resistance, insulation thickness	Calculation of a building's energy efficiency and thermal performance
Oscillation period, resonance phenomenon	Construction Mechanics	Natural frequency of a building, inertial damper	Development of earthquake-resistant structural solutions

The process of forming professional competence in future civil engineers consists of three interconnected stages [14,15]:

*Stage I: Preparatory–Theoretical.*

At this stage, physical laws are contextualized within an engineering framework (for example, interpreting Fourier's Law in terms of heat flux through building envelopes). Students learn to correlate physical concepts with their engineering equivalents.

*Stage II: Practical–Integrative.*

This stage transforms theoretical knowledge into practical skills. Integrative laboratory sessions serve as the principal mechanism, allowing students to apply physical laws to real engineering problems.

*Stage III: Application–Assessment.*

Students' ability to apply acquired knowledge is evaluated through complex engineering tasks and project-based assignments. This stage confirms the level of professional competence achieved.

The formation of professional competence in students is not the responsibility of specialized engineering disciplines alone; it is a systematic process that is strengthened through the integration of physics with general engineering requirements. Such integration enables graduates to make well-informed professional decisions grounded in theoretical knowledge.

Thus, the integration of physics into general engineering disciplines is achieved through the consistent application of core physical concepts. Adapting physics to the fields of architecture and construction creates a solid foundation for developing students' professional competencies. The incorporation of physical concepts into construction-related subjects helps eliminate methodological gaps within the educational process. As a result, physics becomes not an abstract theoretical discipline but a fundamental and practical basis for all engineering solutions in architecture and construction.

Enhancing the teaching of physics through integration with architectural and construction sciences represents a strategic direction in preparing university graduates who can meet the high demands of modern industry. Through this systematic approach, the longstanding discrepancy between theory and practice in engineering education can be effectively reduced.

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## SCIENTIFIC REVIEW

**Title of the article:** *Methodological Foundations for Improving the Teaching of Physics Based on the Integration of Architecture and Construction*

**Author:** *Abror Nortojoyev, PhD in Pedagogical Sciences, Associate Professor at the Tashkent University of Architecture and Civil Engineering.*

The article presents a well-structured and methodologically rich investigation into the integration of physics with architecture and construction sciences in technical higher education institutions. The author addresses an increasingly relevant issue in engineering pedagogy: the alignment of fundamental scientific knowledge with practical professional training within the context of the credit-modular education system. The study is timely, responds to the challenges posed by reduced classroom hours in physics instruction, and offers grounded pedagogical solutions based on interdisciplinary integration.

The paper demonstrates solid scientific rigor, draws on international didactic experience, and offers clear methodological recommendations. It successfully connects theoretical constructs with practical applications in engineering curricula, which significantly strengthens its relevance and contribution to modern educational science.

The principal strength of the article lies in its systematic conceptualization of disciplinary integration. The author: a) clearly identifies the set of core physical concepts essential for engineering disciplines; b) demonstrates their functional equivalence in construction engineering subjects; v) formulates improved thematic blocks that ensure meaningful integration into curricula.

This systematic mapping – which includes well-constructed tables linking physical and engineering categories – is original and pedagogically valuable. It provides a practical framework for curriculum designers and educators tasked with strengthening interdisciplinary coherence in engineering education.

The article's originality also stems from its competency-based approach, grounded in contemporary international standards. The proposed three-stage model of competence formation (*preparatory – theoretical → practical – integrative → application – assessment*) is clear, coherent, and methodologically justified. It offers an effective instructional strategy adaptable to various engineering programs.

The article is logically organized, with a consistent flow from problem statement to analysis and pedagogical recommendations. The methodological foundation is sound, drawing from recognized sources in physics education, engineering didactics, and competency-based learning.

Key methodological strengths include:

- A convincing justification for the need for interdisciplinary integration under the constraints of credit-modular education.
- Effective demonstration of how physics underpins professional problem-solving in mechanics, building physics, materials science, and seismic design.
- Comprehensive tables that enhance the clarity and applicability of the proposed integration methods.
- Balanced use of theoretical references and practical examples, ensuring both scientific depth and pedagogical utility.

The study's academic language is consistent with international scholarly standards, and the argumentation is developed with precision and clarity.

One of the most valuable aspects of the article is its explicit orientation toward professional competence development. The author accurately identifies the professional qualities required of future engineers – motivation, inventive thinking, managerial abilities, information literacy, and self-directed learning – and connects these qualities to the didactic potential of integrated physics instruction.

The recommendations given (*synchronization of department activities, formation of interdisciplinary “bridges,” use of software-supported learning technologies*) are practical and actionable. They can readily be implemented in technical universities seeking to modernize their engineering education frameworks.

The tables illustrating links between physics and engineering concepts make the article an excellent resource for curriculum design, interdisciplinary course planning, and methodological seminars for engineering faculty.

**While the article is strong overall, a few areas could be enhanced in future research:**

*Empirical validation.*

The work is conceptual and methodological; future studies might include empirical evidence – such as student performance data or case studies from pilot curricula – to reinforce the conclusions.

*Technological integration.*

The article touches upon digital resources but could further address the role of simulation software, virtual laboratories, and engineering modeling tools in facilitating physics – engineering integration.

*Assessment methodology.*

Although the three-stage model is convincing, a more detailed discussion of assessment instruments (*rubrics, competency benchmarks, integrative tasks*) would strengthen the practical dimension.

These remarks do not detract from the scientific value of the work but rather point toward promising directions for further research.

Overall, the article by Abror Nortojoyev represents a significant contribution to the methodology of teaching physics in technical universities. It offers a logically developed, scientifically justified, and practically relevant framework for integrating physics with architecture and construction sciences. The proposed approach effectively bridges the gap between theoretical scientific knowledge and professional engineering training, making the work highly valuable for educators, curriculum developers, and researchers in engineering pedagogy. The article fully meets the requirements for scholarly publication and is well-deserving of acceptance.

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