DOI: 10.17747/2618-947X-2026-1-47-62

Engineering and Economic Education for Technological Leadership: A Manifesto for Discussion

L.D. Gitelman[1]
M.V. Kozhevnikov[1]
[1] Ural Federal University named after the first President of Russia B.N. Yeltsin (Ekaterinburg, Russia)

Abstract

The article substantiates the need to significantly strengthening engineering and economic education as a critical factor in achieving innovative leadership amid digital transformation and escalating shock changes. It identifies a systemic gap between engineering, economic, and managerial training, which results in low market demand for technological solutions and limits their scalability and competitiveness. The novelty of the study lies in the development of a comprehensive methodology for engineering and economic design that fosters specialists' ability to "think from the future," that is, to engage in proactive management and the design of leadership strategies. The article presents the authors' experience in developing and using a specialized scientific and educational platform, a digital teaching-and-training complex, and simulators as tools for advanced training in relevant competencies. The recommendations formulated in the article are proposed by the authors as a discussion document for the professional community.

Keywords: digitalization, interdisciplinarity, engineering and economic design, advanced training, scientific and educational platform

For citation:

Gitelman L.D., Kozhevnikov M.V. (2026). Engineering and Economic Education for Technological Leadership: A Manifesto for Discussion. *Strategic Decisions and Risk Management*, 17(1): 47-62. DOI: 10.17747/2618-947X-2026-1-47-62. (In Russ.)

Acknowledgements

The study was supported by the Ministry of Science and Higher Education of the Russian Federation under the development program of Ural Federal University named after the first President of Russia B.N. Yeltsin, within the framework of the Priority 2030 strategic academic leadership program.

面向技术领导力的工程—经济教育:一份供讨论的宣言

L.D. Gitelman[1]
M.V. Kozhevnikov[1]
[1]俄罗斯斯联邦首任总统 B.N. 叶利钦命名乌拉尔联邦大学（叶卡捷琳堡，俄罗斯）

摘要

本文论证了在数字化转型加速推进和不确定性不断加剧的背景下，大幅加强工程—经济教育作为实现创新优势关键因素的必要性。研究揭示了工程、经济与管理人才培养之间存在系统性脱节，这种脱节导致技术解决方案在市场上的市场需求不足、可扩展性较弱以及竞争力不强。本文的创新之处在于构建了一套完整的工程—经济设计方法论，培养专业人员"从未来出发思考"的能力，即开展前瞻性管理和引领性战略设计的能力。文章还介绍了专业化科研教育平台、数字化教学培训综合体及模拟训练系统的开发与应用经验，这些工具被用作开展前瞻性能力培养的手段。文中提出的建议被作者作为一份纲领性文件，供专业共同体讨论。

关键词： 数字化，跨学科性，工程—经济项目，超前学习，科研教育平台

引用格式：

Gitelman L.D., Kozhevnikov M.V. (2026)。面向技术领导力的工程—经济教育：一份供讨论的宣言。战略决策与风险管理, 17(1): 47–62. DOI: 10.17747/2618-947X-2026-1-47-62. （俄文）

致谢

本研究得到俄罗斯联邦科学与高等教育部的财政支持，作为以俄罗斯首任总统 B.N. 叶利钦命名的乌拉尔联邦大学发展计划的一部分，并依照"优先级-2030"战略学术引领计划实施。

1. The Challenge: New Priorities Misaligned with Existing Competencies

Today's economy is marked by rapid technological change unfolding in an environment of extreme uncertainty. Digital infrastructure has become ubiquitous, permeating virtually every sphere of activity. Artificial intelligence (AI), predictive analytics, and digital twins make it possible to generate solutions within seconds through the real-time processing of massive volumes of unstructured data. Through the integration of sensors, human-machine interfaces, and the Internet of Things, production systems are evolving into cyber-physical systems in which equipment can transmit real-time performance data directly to enterprise resource planning (ERP) systems, enabling more efficient asset utilization and helping prevent operational disruptions and accidents [Kravchenko, 2025; Loginov et al., 2025].[1]

The pace of these changes is so intense that science is struggling to conceptualize them, while education lags even further behind in updating knowledge, competencies, and training models adequate to this new reality.

In this context, the state's strategic objective of achieving technological leadership in key industries depends to a large extent on its ability to introduce scalable innovations quickly, at lower cost, and with minimal risk. It is no longer enough to develop equipment or technologies with superior functional characteristics. They must also prove effective throughout their entire life cycle and possess a competitive market value already embedded at the earliest stages of innovation and design. In rapidly evolving sectors such as energy, aerospace, mechanical engineering, electrical engineering, transport, and telecommunications, the competency gap is becoming a major constraint on development.

The problem becomes especially acute when an economy must rapidly transition to a new model based on advanced scientific and technological achievements, intelligent production systems, neural-network technologies, and robotics. Under such conditions, the shortage of specialists capable of formulating tasks for these highly complex systems and interpreting not only their outputs but also their decisions in the shared language of engineering, economics, and IT is becoming increasingly evident [Gitelman et al., 2024].

What is now urgently needed is engineering and economic training for innovation-oriented professionals. The old model of professional education is no longer merely outdated; it is actively impeding development and generating losses. This problem must be addressed without delay.

A vivid example of the consequences of underestimating the importance of engineering and economic knowledge and competencies in large-scale innovation projects is the failure of the energy transition in many industrialized countries [Heinberg, 2022; Gitelman et al., 2023; Ahmed et al., 2025]. A mission driven by noble goals turned into an investment failure that might have been avoided had decision-makers and their advisers possessed even a basic grounding in engineering economics.

A major reason for this outcome was the failure to account for the technological specifics of the electric power industry and for the way these specifics are linked both to the sector's economic performance and to other sectors of the economy:

1. Insufficient consideration was given to the intermittent nature of wind and solar generation.
2. The economics of energy storage were not fully assessed, including end-of-life disposal; the cost of utility-scale storage makes green energy economically unviable without substantial subsidies.
3. Energy-transition programs were poorly aligned with the technological requirements for electricity and heat at industrial enterprises, which remain major sources of harmful emissions. As a result, industry found itself caught between two imperatives: decarbonization and the inability to ensure reliable energy supply without conventional generation.
4. Policymakers ignored a fundamental principle of engineering economics: reliable power supply is never cheap, but the absence of reliability is always more expensive.

These obvious failures effectively undermined the vision promoted by advocates of the energy transition:

- In engineering design, the behavior of power systems under large-scale integration of intermittent renewable energy sources was not properly modeled; nor was sufficient analysis conducted regarding the need for flexible capacity—such as pumped-storage hydro plants, gas-fired peaking plants, and storage systems—to offset downtime at wind and solar facilities.
- In economic modeling and risk assessment, the economics of the transition were calculated on the basis of average gas prices and equipment costs, without taking their volatility into account. Nor was adequate attention paid to the fact that the decommissioning of nuclear and coal-fired power plants made EU economies more vulnerable to climatic anomalies and geopolitical shocks.
- In environmental and sustainability assessment, no full life-cycle cost evaluation of green technologies was carried out. The production of solar panels and wind turbines requires vast amounts of rare-earth metals; their extraction and processing inflict serious environmental damage on supplier regions, while the disposal of end-of-life equipment remains unresolved [Fotis et al., 2025; Uchman et al., 2026].

The energy-transition case clearly shows that every technological solution has an economic dimension [Gitelman et al., 2023], and ignoring that dimension leads to major losses. This principle should be central to the edu-

[1] See also: https://национальныепроекты.рф/upload/doklad-cifra-2025/doklad-cifra-2025.pdf.

cation of the next generation of engineers, as well as economists, managers, and IT specialists. An engineer must be able to see the economic implications of every technical decision from the moment it is conceived: payback, sensitivity to market conditions, and attractiveness to investors. An economist must understand the physical nature of the assets being evaluated, their technological constraints, operating modes, wear patterns, and failure risks. A manager must possess enough technological literacy to manage projects with a clear understanding of scientific and technological trends and stakeholder interests. An IT specialist, in turn, must understand the business consequences of architectural decisions in terms of value creation and cost reduction.

2. Principles for Organizing Engineering and Economic Training for Innovation Personnel

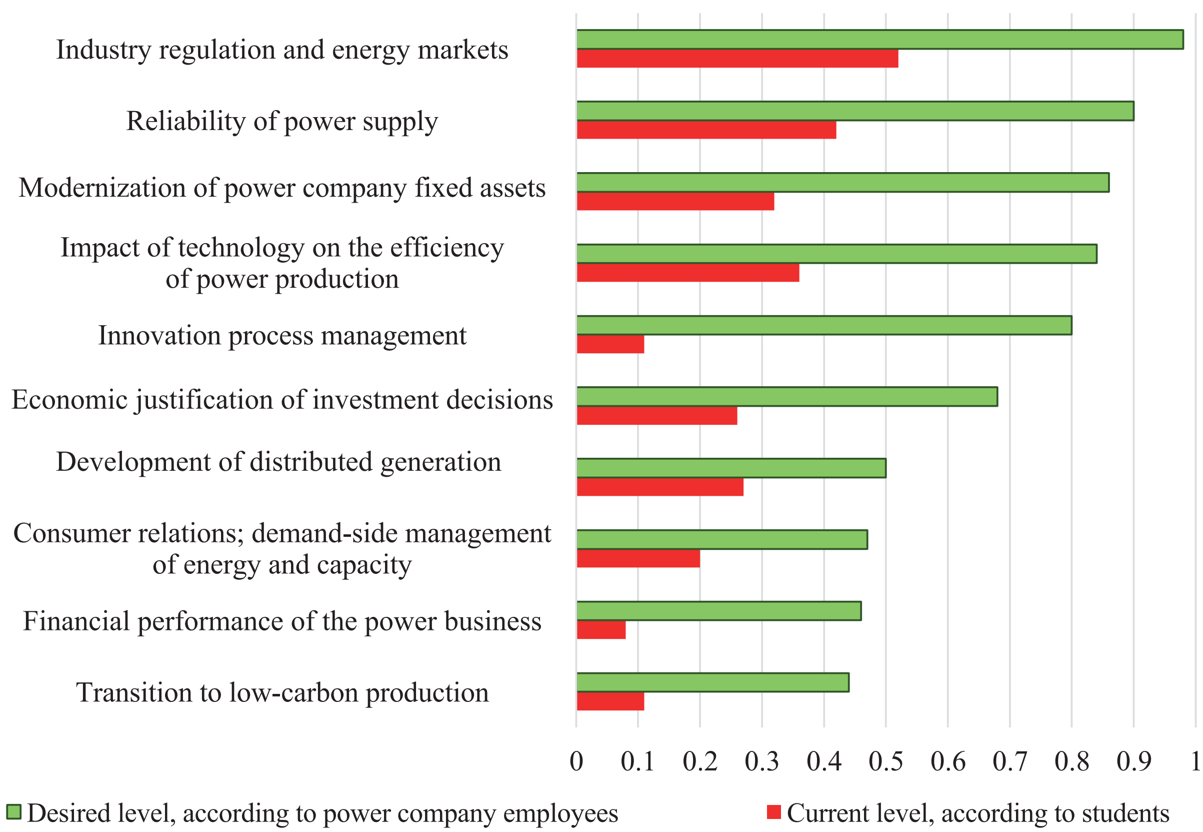
A central objective of engineering and economic training is to develop in specialists not only the ability to create a unique technical prototype, but above all the ability to ensure its market viability in large-scale production, that is, its scalability; to build an adequate business model, typically grounded in digital technologies; and to organize the innovation process effectively. This was a bottleneck in Soviet industry and remains one in Russia today: the country has still not succeeded in establishing competitive mass production in such sectors as automotive manufacturing, computer equipment, electronics, and household appliances. In highly competitive markets, it is essential to align the technical feasibility of a new product with the ability to produce it faster, at lower cost, with higher quality, and with greater consumer appeal than competing alternatives. Yet these are precisely the capabilities that engineers, economists, managers, and IT specialists are not being taught today.

As shown by the analysis presented in [Gitelman, Kozhevnikov, 2025], engineering education largely overlooks the interdisciplinary connections among technology, ecology, economics, and management, as well as topics of immediate relevance to modern industries, such as demand-side management and the energy transition (Figure 1).

At the same time, according to practicing specialists, these issues should be covered in far greater depth and scope, while the growing importance of competencies related to organizing innovation processes points to their relevance and acute shortage not only among engineers but also among managers at all levels (Table 1).

Let us formulate the key principles of a new type of engineering and economic training.

It is fundamentally important to begin this training in the



Source: compiled by the authors.

Fig. 1. Depth of Consideration of Engineering and Economic Issues in the Electric Power Industry Development

first year of study. As psychological research suggests, once a person has developed, by the age of 25–30, a mode of thinking based on rigid dichotomies that treat engineering and economics as mutually exclusive categories, it becomes extremely difficult to retrain them to think in interdisciplinary terms [Phan, Ngu, 2021; Ionescu et al., 2023]. By contrast, engineering and economic thinking is the ability to recognize the interdisciplinary nature of any professional decision. Specialists with this type of thinking, who are especially in demand in today's labor market, ask questions at the intersection of disciplines, such as: "How can a reliable design be developed within budget while ensuring an acceptable operating cost?" and "How can a project be made profitable while taking technological constraints and production risks into account?"

This kind of hybrid thinking cannot be developed in the later years of study simply by adding a course such as "Economics for Engineers" to the curriculum, because by that stage the student's intellectual lens has already been formed: they are accustomed to viewing a problem from only one perspective, either technical or economic. From the first year onward, therefore, students should simultaneously deepen their understanding of:

– their industry, including how value chains are organized and who the key players are;
– technologies and the specific features of production organization, including the main business processes, how the product is created, what it is made of, what costs are involved, and what physical, chemical, and software-related constraints must be taken into account. An engineer who has never been inside a production shop and an economist who does not understand how the production cycle is organized will speak different professional languages and make decisions that cannot be implemented;
– real business problems, including unmet customer needs and the reasons why some technologies gain market traction while others do not.

The main task for the student here is to see and understand how disciplinary fields intersect and enrich one another. They should not have to wait until the senior years to encounter special interdisciplinary courses. Engineering-and-economic thinking takes shape when, already in the first year, while studying, for example, strength of materials, a future engineer sees that the strength equation is linked to the choice of material, the choice of material is linked to its cost, and cost is linked to the market price of the product. A future manager or economist, when studying the fundamentals of investment management, should be able to see the real technological constraints behind financial indicators. Thus, choosing a cheaper solution that appears profitable in the short term may ultimately lead to lower equipment reliability, increased risks of accidents and operational disruptions, and, consequently, growing losses and declining trust on the part of consumers and investors over the long term.

Table 1
Main Barriers in Managerial Practice in the Electric Power Industry

Deficiency	Share of respondents reporting a pronounced manifestation of the deficiency (%)	
	2020	2025
Lack of competencies in innovation process management (investment appraisal, assessment of expected benefits and risks, employee engagement, teamwork)	42	72
Insufficient efforts to attract and develop young specialists for work on innovation projects	70	68
Lack of knowledge and practical experience in implementing digital tools and IT solutions in the company's operations	47	54
Poor understanding of the benefits that additional products and services, including digital ones, can bring to a power company beyond its core operations	72	46
Inability to respond in a timely manner to market changes and consumer needs	25	40
Lack of a project-based thinking and project management skills	48	38
Inconsistent and contradictory managerial decisions caused by a poor understanding of the interests of key stakeholders	17	36

Source: compiled by the authors.

These linkages must be embedded in the curriculum from the outset. Only then will students come to understand that engineering and economics are inseparable dimensions of the outcomes by which their work will ultimately be evaluated. That is why a model engineering-and-economic program should introduce students, from the very beginning of their studies, to the operation of advanced industrial facilities, helping them enter the profession and develop a real understanding of their industry and its connections with other sectors of the economy. In fields such as the electric power industry, nuclear power, petrochemical production, and transport, where reliability, environmental safety, and the human factor are of paramount importance, this sense of the industry is especially critical—and it cannot be developed in just one or two years.

A substantial expansion of enterprise-based practical training, with students involved from the early years of study in both operational and innovation-related tasks relevant to their future profession, is a policy decision that needs to be made at the state level.

Table 2 presents an example of a forward-looking specialist degree program for engineer-economists in the electric power industry. The program is balanced in its combination of fundamental and applied training as well as in its set of disciplines. It fosters an integrated understanding of the logic of scientific and technological progress and equips students with the tools needed to implement relevant innovation projects.

A strong emphasis on interdisciplinarity is built into the curriculum from the first year of study, enabling students to:

– develop an understanding of technologies and production systems as complex and socially responsible objects of management;
– learn to analyze the interrelationships among engineering, technology, ecology, economics, and management, including advanced IT systems and digitalization, in order to make sound decisions on business development, business process improvement, and the development of companies' areas of activity.

Table 2
A Fragment of the Engineering and Economics Degree Program Framework for the Electric Power Industry

<table>
<tr><th rowspan="3">Key Disciplines</th><th colspan="5">Years of Study</th></tr>
<tr><th>Year 1</th><th>Year 2</th><th>Year 3</th><th>Year 4</th><th>Year 5</th></tr>
<tr><td>Introduction to the Field
Patterns of Scientific and Technological Development
General Mathematics
Economics and Organization of Energy Markets</td><td>Организация энOrganization of Power Production
Advanced Digital Technologies and AI
Applied Mathematics and Statistics</td><td>Economics of the Industry
Business Infrastructure of the Power Industry
Financial Mathematics
Investment and Risk Management</td><td>Production Asset Management in Power Companies
Strategic Management Under Uncertainty
Framing Engineering and Economic Problems
Investment Project Management
Personnel and Team Development</td><td>Business Analytics
Power Industry Engineering and Consulting</td></tr>
<tr><th rowspan="4">Main Active Learning Methods</th><td colspan="4">Interdisciplinary business simulations</td><td>Internships at power facilities</td></tr>
<tr><td colspan="3">Innovation-focused company visits</td><td rowspan="2">Workshops led by senior executives</td><td rowspan="3">Pre-defense presentations of final projects at power companies</td></tr>
<tr><td rowspan="2">Professional challenge tasks</td><td rowspan="2">Power production improvement projects</td><td>Analysis of companies' financial statements</td></tr>
<tr><td>Quantitative case studies</td><td>Management case studies</td></tr>
<tr><th>Type and Duration of Practical Training</th><td>Research internship (4 weeks)</td><td>Technical internship in a production unit of a power company (4 weeks)</td><td>Internship in the chosen specialization within a functional unit (4 weeks)</td><td>Engineering and economic internship in corporate management (8 weeks)</td><td>Pre-graduation internship combined with with managerial shadowing (16 weeks)</td></tr>
</table>

Source: compiled by the authors.

A related issue is the training of engineering personnel and the need to strengthen its engineering-and-economic component. As noted above, any engineering decision aimed at improving the technological level of production is inherently also a techno-economic decision. Ultimately, such decisions are evaluated in terms of the balance between their economic, environmental, and social outcomes and the financial resources required to achieve them. Engineering education must therefore include the corresponding organizational and economic dimensions. The most important of these are outlined below using the electric power industry as an example.

1. Industry organization and energy markets. The system of state regulation and governance in the industry. The effectiveness of market reforms in the electric power sector. Long-term industry development programs.
2. Efficiency of power production. Relationships between the technical characteristics of power installations and the environmental and economic performance of power companies.
3. Availability and reliability as the core functional characteristics of power facilities. The effect of availability on the economics of a power company. Assessing the cost-effectiveness of expenditures aimed at improving reliability. Advanced approaches to organizing maintenance and repair.
4. Production asset management. Renewal of the fixed assets of power companies. Equipment modernization, reconstruction, and technical upgrading of power facilities.
5. Financial resources of power companies.
6. Economic justification of investment decisions and projects. Taking technical and price risks into account when evaluating investment projects.
7. Innovation process management. Stages of the innovation process in a power company. Advanced technological innovations for power plants and grid companies. The impact of these changes on the profitability of power companies, production costs, and electricity prices. Energy engineering as an advanced tool for innovation process management.
8. Transition to low-carbon production.
9. Development of distributed generation.
10. Demand-side management of energy and capacity.
11. Digital transformation of power production and management.

It should be emphasized that engineering training remains incomplete unless the economic component of students' graduation projects is developed to a professional standard under the supervision of leading faculty members from specialized departments of economics and management. Without this component, the graduation project fails to develop the most important competency: the future engineer's ability to justify why a particular technical solution merits investment and how it will affect business performance. As a result, graduates enter the profession without having learned to connect engineering thinking with economic outcomes.

3. Special Emphasis on Fundamental Knowledge

A matter of ongoing debate is the so-called fundamental core of engineering-and-economic education. In our view, it should encompass three priority areas:

1) the scientific and technological foundations of industrial production, including digitalization, without which it is impossible to develop an integrated understanding of the objects and tasks of one's professional activity, recognize key development trends, or prepare even for the near future;
2) the methodology of innovation activity;
3) the design of complex systems and systems engineering [Gitelman et al., 2022b].

These areas define the content of the corresponding core disciplines needed in the education of engineers, managers, and economists alike (Figure 2). As a result, the content of fundamental training changes substantially across levels of education: at the undergraduate level, the focus is on specific fields of knowledge such as economics, engineering, and computer science, whereas at the master's level attention shifts to complex objects and processes, including the development of complex systems, strategic analytics, and future-oriented design.

An alternative structure for the fundamental component is also possible. In this approach, the curriculum is built around a relatively small number of core required courses that foster systems thinking and provide the mathematical foundation needed to address complex problems, as is common at leading universities worldwide [Reynolds, 2024]. These courses are complemented by a range of electives that broaden students' intellectual horizons and encourage greater flexibility of thought (Table 3).

Effective implementation of a stronger fundamental component would, of course, require changes in the set of entrance examinations and a higher admission threshold.

Under the Soviet education system, students entering either engineering or economics were expected to have a strong foundation in mathematics and the natural sciences. Even specialized economics institutes treated physics and advanced mathematics as essential subjects, recognizing that industry, energy, and transport cannot be managed effectively without an understanding of the physical processes that underpin them.

Today, most Russian universities admit applicants to economics and management programs with only a basic level of mathematics, and physics is often not required at all. As a result, many graduates have little understanding of technological constraints, are unable to estimate

Source: compiled by the authors.

Fig. 2. The Author's Experience in Delivering Fundamental Training

production costs realistically, base managerial decisions on abstract reasoning, and struggle to work effectively with engineers. At a time when technological leadership and sovereignty have become national priorities, this situation is untenable. In our view, admission to economics and management programs should therefore require advanced mathematics, physics, and computer science, given the central role of digital technologies in the modern world.

China offers a revealing contrast. Admission to economics and management programs—especially at leading universities that train highly qualified specialists—typically requires strong preparation in advanced mathematics and the natural sciences. The gaokao, the national university entrance examination, includes mathematics and physics as core subjects for most engineering-and-economics tracks [Zhang, Pecheritsa, 2025]. The United States does not have a single national admissions standard, but leading universities generally expect applicants to undergraduate programs in economics and management to have a strong secondary-school background in mathematics, sometimes including introductory calculus, as well as in the natural sciences;

Table 3
Proposed Structure of Fundamental Training

Type of Discipline	Cource Title	Purpose
Core	Systems Analysis and Complexity Theory	Develops the ability to view systems holistically and understand the interrelationships among technical, economic, and organizational subsystems
	Mathematical and Simulation Modeling	Provides a common language and toolkit for describing, forecasting, and testing techno-economic processes without risking disruption to real-world production
Elective	Decision Theory under Uncertainty	Introduces tools for risk analysis, multicriteria decision-making, and scenario-based reasoning
	Life-Cycle Management of Complex Systems	Integrates design, economics, and management across the full life cycle of complex systems
	Fundamentals of Production Technology and Organization	Develops an understanding of technological constraints and real-world production processes
	Innovation Economics and R&D Management	Connects engineering creativity, economic efficiency, and innovation management
	Digital Transformation and Cyber-Physical Systems	Integrates digital technologies with production systems and economic decision-making
	Methodology of Interdisciplinary Research	Develops the ability to synthesize knowledge across fields and formulate problems at the intersection of disciplines

Source: compiled by the authors.

and at engineering schools that train future managers, physics is a required subject [Bouchrika, 2026].

4. Engineering and Economic Education in International Practice

An analysis of the curricula of engineering and economic programs offered by foreign universities reveals several major types [Gitelman et al., 2022a].

In programs designed to provide broad-based preparation for future managers, the curriculum can be broadly divided into two blocks: traditional subjects, such as finance and economics, accounting, quality management, human resource management, and operations management; and interdisciplinary subjects focused on the technological dimension of business, including systems engineering, innovation development in engineering and management, information and analytical systems, business modeling, and the management of industrial and business development projects.

Programs intended to prepare managers for specific industries characterized by greater technological complexity require students to study the technological specifics of production alongside the organizational and economic aspects of innovation activity.

Of particular interest to us are advanced programs aimed at training innovation-oriented specialists capable of developing, mastering, testing, and implementing the technologies of the future in engineering, IT, and the environmental sector. Illustrative examples include programs offered by Stanford University and the Massachusetts Institute of Technology (MIT).

Stanford's engineering management program is organized around six research areas that are directly integrated into the curriculum at both the undergraduate and graduate levels: computational social science; decision-making and risk analysis; operations research; organizations, technology, and entrepreneurship; policy and strategy; and quantitative methods of financial analysis. Among the key learning outcomes are mastery of mathematical methods, the ability to plan and conduct experiments, and the ability to design complex systems using systems engineering tools.

At MIT, the System Design and Management program is organized into three components. The first consists of core courses in engineering and management totaling 36 credit units. The second includes required advanced courses—12 credit units in engineering and 12 in management. The third comprises student electives, with a broad selection of approximately 150 engineering courses, 50 management courses, and 30 interdisciplinary courses.

The architecture of such programs is generally based on the principles of STEM, understood as the integration of Science, Technology, Engineering, and Mathematics [Gromova et al., 2025; Torralba, Membrillo-Hernández, 2025]. STEM is viewed as a concept of interdisciplinary, problem-based learning that engages students in:

- activities related to the design, development, and operation of technological systems;
- case-based discussions of current issues in science, technology, and the social sphere;
- addressing the challenges faced by specific industries and companies through the application of fundamental scientific knowledge and an understanding of technological development;
- individual and team-based work on problems characterized by a high degree of uncertainty.

In recent years, one of the main forces shaping engineering and economic education worldwide has been the rapid advance of digital technologies. In China, for example, the state has explicitly defined the digital economy as a driver of technological leadership, artificial intelligence as a source of competitive advantage, and higher education that integrates cutting-edge digital and AI technologies as a key engine of innovation [Chentsova, Chentsov, 2023]. A striking example is Chongqing University of Science and Technology, where students in the School of Civil Engineering are trained through a multi-level integration of AI tools, including digital twins for assignments, neural-network-based generation of images and digital avatars for case development, and simulation platforms for visualizing financial evaluations[2].

The American approach is equally instructive. One of the defining trends in the United States today is close collaboration with industry combined with a strong emphasis on AI-related career pathways.

Texas A&M University, together with the Microsoft AI Economy Institute, is implementing a project titled "The Evolving Role of Universities in the Age of AI: Opportunities to Advance AI Literacy through Interdisciplinary Curriculum Design." The project examines how universities can prepare students for the labor market by embedding competencies in big data, machine learning, and AI ethics into academic programs[3].

At Carnegie Mellon University, the master's program in business technology strategy prepares specialists to apply AI to breakthrough challenges at the intersection of engineering, economics, and information technology. As part of dedicated project-based practicums, students develop neural-network models for analyzing market trends, simulation environments for testing complex scenarios using large language models, and AI assistants to support decision-making in dynamic and uncertain environments[4].

The Chinese and American examples discussed above confirm that the future of engineering and economic edu-

[2] Deng Y. Chongqing University Launches AI-Powered Courses. https://app.ichongqing.info/mixmedia/a/202503/12/WS67d18bdfe4b0f27cb3591f03.html.
[3] Texas A&M Energy Institute Partners with Microsoft AI Economy Institute to Advance AI Literacy and Workforce Readiness. https://energy.tamu.edu/news_item/texas-am-energy-institute-partners-with-microsoft-ai-economy-institute-to-advance-ai-literacy-and-workforce-readiness/.
[4] Signature Initiative: Collaborative AI. https://tepper.pantheon.cmu.edu/tepper/about/strategic-plan/signature-initiative-collaborative-ai.

cation lies in embedding digital tools and artificial intelligence at its core.

5. A Method for Aligning Engineering and Economic Education with Technological Leadership

The method of the Engineering and Economic Project of technological leadership (hereinafter, EEP), developed at the Department of Energy and Industrial Management Systems of Ural Federal University, is built around a vision of the future of an industry or enterprise. It identifies the competencies needed to realize that vision, addresses the resulting skills gap through anticipatory training, and turns engineering and economic education into both a methodological framework and a practical instrument for implementing a leadership strategy[5].

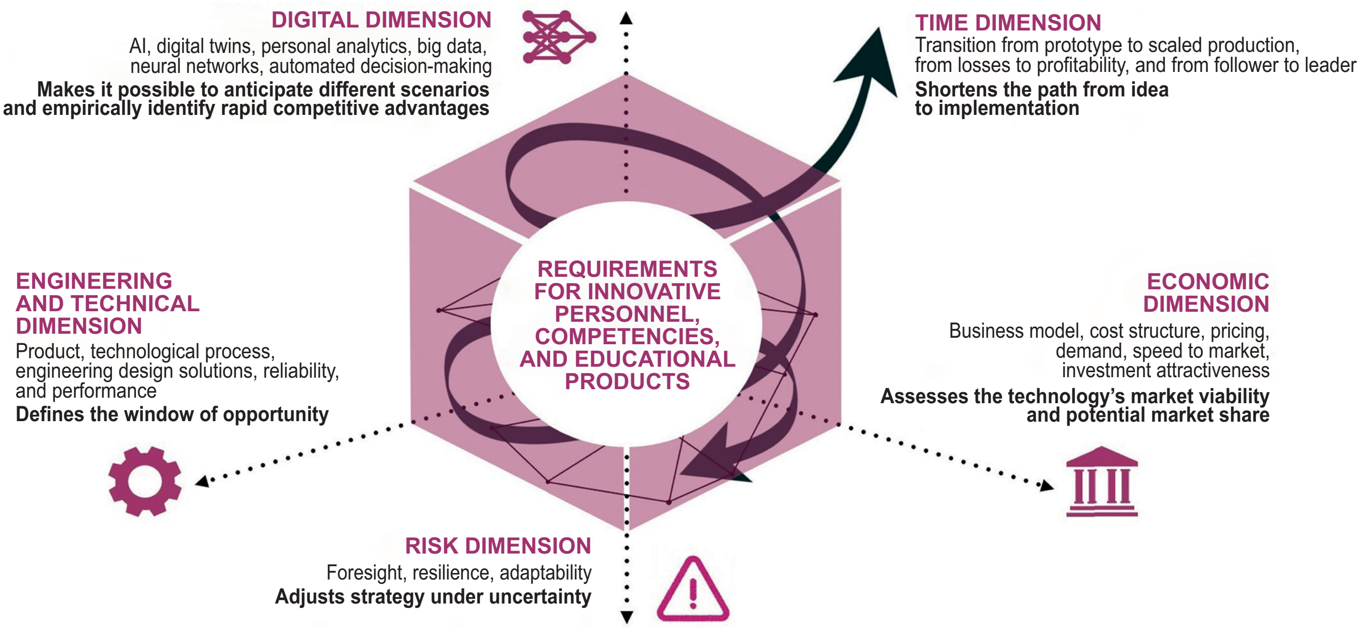
As noted in our earlier publications [Gitelman, Kozhevnikov, 2025; Gitelman et al., 2025], EEP performs an integrating function by aligning the economic interests of producers and consumers when assessing the market viability of engineering solutions. In this context, the EEP is described as a multidimensional model in which four different coexist and influence one another in real time (Figure 3).

A distinctive feature of the EEP method is that it structures the innovation process around a forward-looking logic that the authors describe as "thinking from the future." Unlike a conventional techno-economic feasibility study, it is closely linked to anticipatory management [Gitelman, 2020], oriented toward future conditions, and built on scenario-based modeling under uncertainty. Rather than being evaluated against a single baseline forecast, a project is assessed across multiple possible futures shaped by technological change, regulatory shifts such as the introduction of a carbon tax, fluctuations in fuel and resource prices, changing consumer preferences, and other risk factors.

It is important to emphasize that, unlike the conventional engineering and economic approach, in which engineers develop technical solutions, economists assess them mainly in cost terms, and environmental specialists address environmental consequences only after implementation, the EEP method requires specialists from different fields to work in an integrated way from the earliest conceptual stage. Each technical solution is therefore assessed simultaneously against several groups of criteria, including:

- technical criteria: reliability, safety, compliance with standards, and digital maturity;
- economic criteria: total cost of ownership over the asset life cycle, payback, and sensitivity to external factors;
- environmental criteria: carbon footprint, environmental impact, recyclability, and compliance with current and anticipated regulatory requirements (Figure 4).

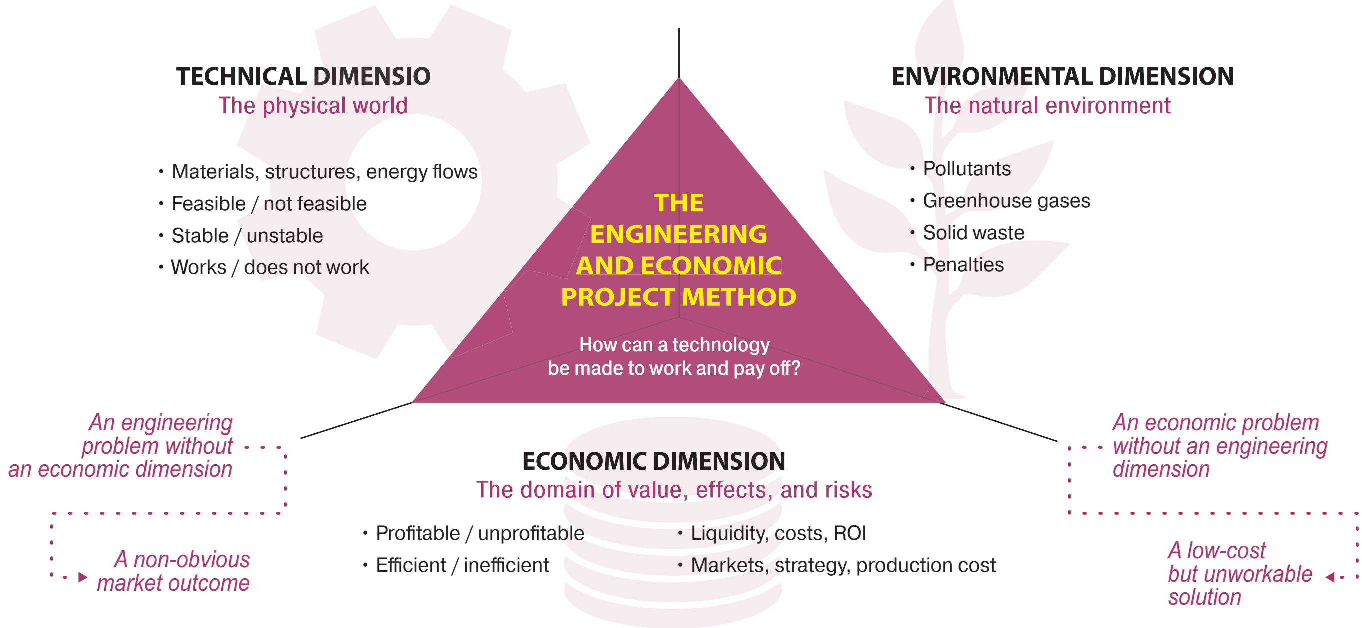
The EEP method creates a fundamentally different educational architecture and makes anticipatory training for technological leadership possible. This is achieved through



Source: compiled by the authors.

Fig. 3. Engineering and Economic Design as a Multidimensional Model

[5] A detailed account of the theoretical foundations and functional capabilities of the EEP is provided in the authors' two forthcoming books, The Engineering and Economic Project: Innovation Personnel and Solutions for Technological Leadership and The Engineering and Economic Project: A Guide to Developing Competencies for Technological Leadership, both of which are currently in press and scheduled for publication in the second quarter of 2026.



Source: compiled by the authors.

Fig. 4. The EED Method: Integrating Engineering Thinking and Market Perspective

a set of interrelated mechanisms embedded in the method itself.

The first of these is specially organized anticipatory problem framing, that is, the systematic identification and formulation of future challenges [Gitelman, 2020]. Traditional education typically gives students problems that already have known solutions. In effect, the past is passed on to the present in the form of ready-made answers. EEP reverses this logic. Instead of solving tasks with predetermined outcomes, students are placed in future-oriented problem situations—challenges industry is likely to face in 5, 10, or 15 years. Using digital tools, they model the production systems of tomorrow while taking into account expected technological shifts, changes in market conditions, the emergence of new materials, new regulatory requirements, and logistical constraints.

The second mechanism is an active innovation process. Students learn to treat the analysis of complex change, continuous problem framing, and the transformation of problems into projects as a normal part of their work. This places particular emphasis on teamwork in a digital environment. The digital platform continuously introduces new variables: energy prices change, a cheaper material appears, new environmental restrictions are imposed, or a competitor launches a breakthrough technology. Each time, students must recalculate the economics of their project and look for new engineering solutions. At the same time, they must collaborate with peers and consult experts, including AI tools, on specific issues. This is how competence in team-based innovation activity is developed.

The third mechanism is the development of a future-driven vision through digital twins. Within the EEP framework, a digital twin helps students conceptualize a product and a production system that will be both effective and in demand under projected future conditions. An AI assistant supports this process by analyzing global trends, identifying the competencies and decisions likely to become critical in the medium term, forecasting possible risks and bottlenecks in emerging technologies, and modeling alternative market scenarios.

The fourth mechanism is integration with systems engineering. Systems engineering offers a toolkit for working with complexity, including holistic vision, requirements management, and architectural thinking. The EEP method complements this toolkit with approaches for assessing efficiency and risk, total cost of ownership, and predictive analytics. Combined with contemporary information technologies, this synthesis enables specialists to design engineering solutions on the basis of a unified techno-economic model that takes account of both economic consequences and market dynamics. The result is a multiplier effect: the thinking of interdisciplinary teams becomes oriented toward the real-world feasibility of projects aimed at future leadership.

Our work in this area has been summarized in monographs [Gavrilova et al., 2017; 2024] and is currently being implemented through the courses Systems Engineering for Managers, Interdisciplinary Industry Linkages, and Production Asset Management System. Students learn to shift their focus from day-to-day operational measures to asset performance over the life cycle and its contribution to profitability—an especially urgent task given the pressing need for systemic industrial modernization.

For example, the course Production Asset Management System develops the following key engineering and economic competencies:

– Techno-economic modeling: the ability to build digital twins that connect the physical parameters of assets, such as efficiency, wear, and vibration, with economic parameters such as repair costs and residual value.
– Life-cycle management: an understanding of how decisions made at the design stage will affect costs over the next 10–20 years.
– Data science: the use of predictive analytics and machine-learning methods to forecast failures and optimize maintenance schedules.
– Fundamentals of financial management applied to assets: repair budgeting, evaluation of investments in specific modernization measures, tax treatment, and depreciation charges, all understood in conjunction with the engineering characteristics of the assets involved.
– Systems thinking: the ability to see an asset as part of a production system in which the downtime of one component affects the entire value chain.

Thus, integrating EEP and systems engineering into educational courses develops cross-cutting competencies that enable graduates and trainees to view assets within a unified framework of technology, economics, and risk; justify investments on the basis of total cost of ownership rather than purchase price alone; work effectively in interdisciplinary teams; and adapt quickly to changes in technology and the market.

6. A Digital Platform for Developing Innovation-Oriented Specialists

Engineering and economic training aimed at developing the competencies required for technological leadership in a digital environment must itself be delivered in a high-tech format aligned with the values and expectations of younger generations. The use of digital twins and simulation platforms makes it possible to model different scenarios, learn from mistakes without serious consequences, and see the long-term effects of decisions. In many industries, including electric power, where the cost of error is especially high, it is essential that students learn to work with real data, interpret modeling results, and make decisions under conditions of uncertainty.

This issue has become especially urgent in light of the rapid advance of AI. Specialists must do more than simply use off-the-shelf AI tools: they need to understand their limitations and combine machine-based analysis with expert judgment. This, in turn, requires academic programs to include dedicated modules on data analysis, machine learning, and AI ethics.

In this regard, the authors' efforts are focused on developing a specialized digital platform for engineering and economic education to support both student training and the development of enterprise personnel reserves. The platform includes the following components:

1. A teaching-and-training complex: a system that integrates educational content, teaching methods, and information support for the study of theoretical issues, research work, and the development of engineering and economic projects (Figure 5).

2. The "Ahead of Time" knowledge base for 24/7 self-study, containing hundreds of electronic resources prepared by department faculty, as well as completed student projects, all of which can be automatically matched to a specific project-and-research topic or learning task.

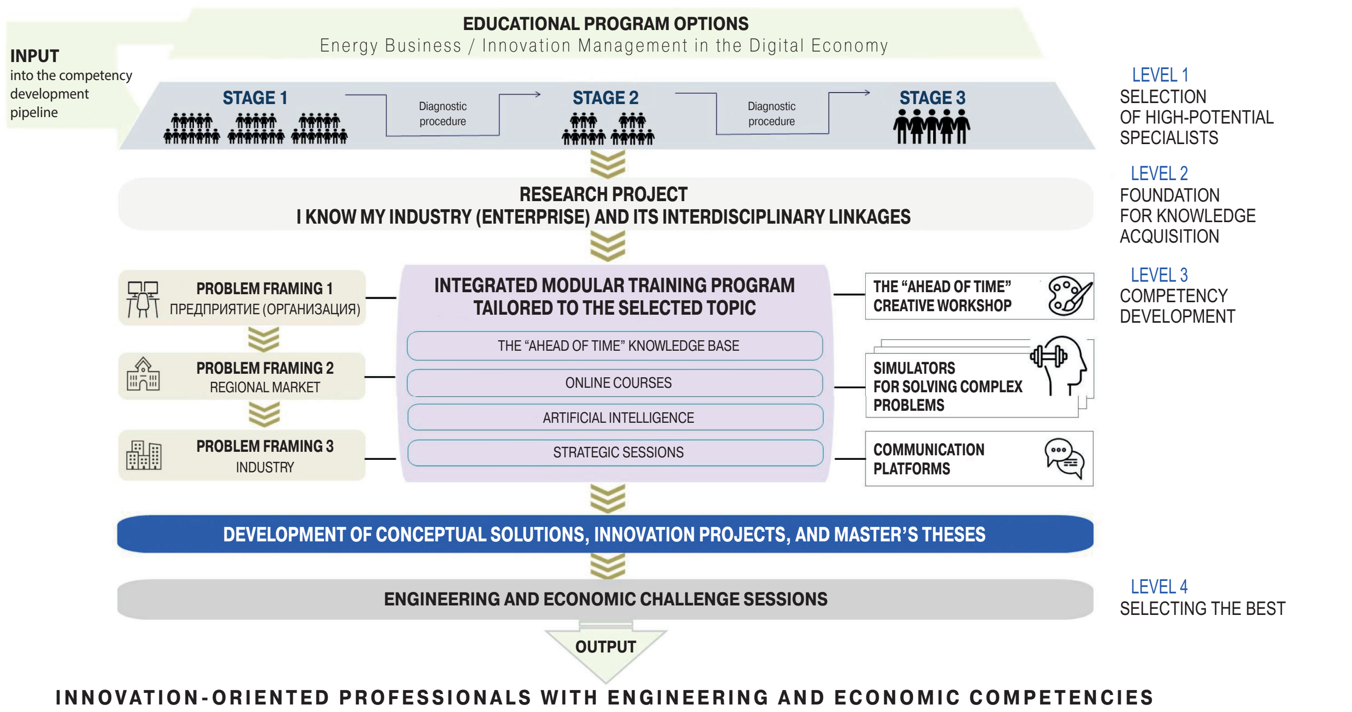
3. A portfolio of online courses that makes it possible to quickly assemble modular educational products tailored to different tasks, competencies, and students' professional interests.

4. Digital simulators for solving complex problems: tools for the intensive development of innovation competencies through electronic interfaces (computer applications) and interactive dialogue with AI, machine-learning systems, expert consultants, and members of the student's own team (Figure 6).

The simulator contains a thematic set of innovation projects and current challenges, and work within it takes the form of developing innovative solutions on a selected topic. To organize a creative yet goal-oriented process, different scenarios of teamwork are used. These include multiple stages that can vary depending on the topic, the scale of the problem being addressed, and the composition of both the innovation participants and the project team.

A range of digital simulators is used in teaching-and-training sessions, and the set is updated as new topics are introduced. The simulators currently in use include "Transformations for Achieving Technological Leadership," "Regional Electric Power Reform After Twenty-Five Years: Assessing the Results," "A Power Company Strategy for Technological Leadership," "Engineering and Economic Problem Framing for Stimulating Innovation," "Process Management as a Foundation for Digitalization," "Innovation Personnel as a Driver of Technological Leadership," "Enterprise Asset Management: Priorities for Anticipatory Management," "Competencies for Modernizing the Electric Power Industry," "Rethinking the Mission of an Enterprise Seeking Technological Leadership," and "Risk Analysis of an Innovation Solution."

5. A set of original technologies for the continuous development of competencies across the full educational pathway, from school, technical school, or college through to master's and doctoral study.

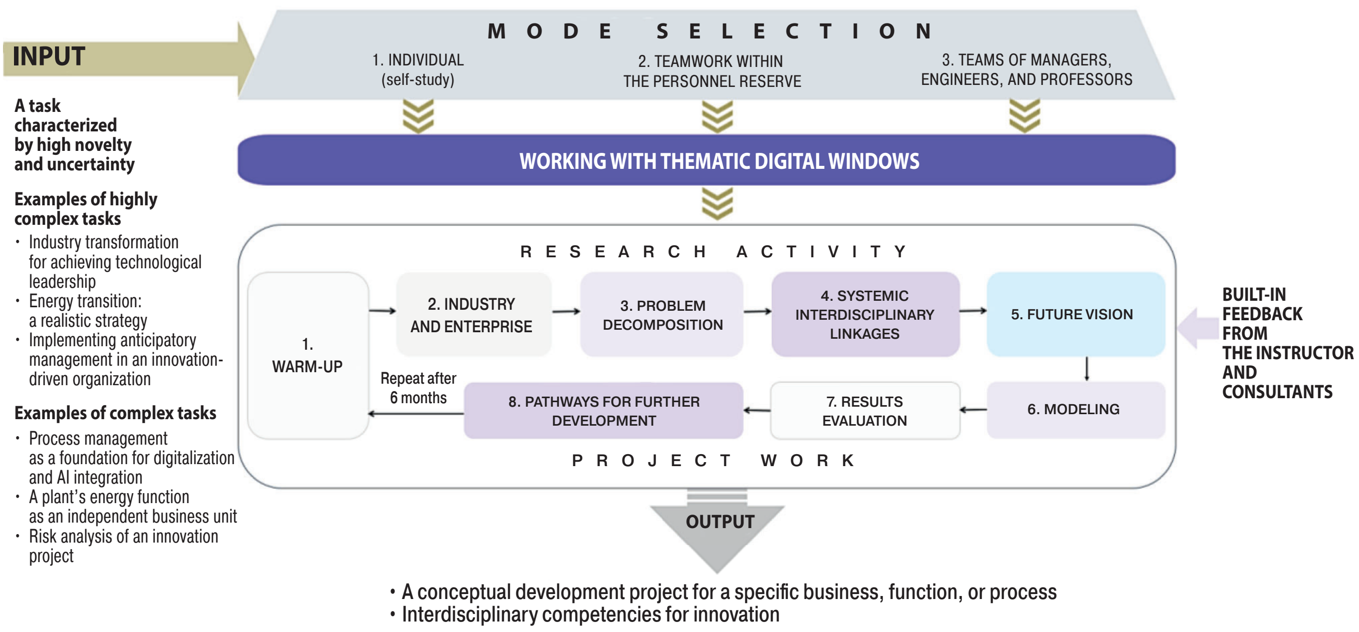


Source: compiled by the authors.

Fig. 5. Organization of Student Work in the Teaching-and-Training Complex

6. A network of communication platforms, including virtual ones, linking the department with leading enterprises and academic partners from different countries and from cities across Russia to exchange best practices and innovative ideas.

At the heart of this research and educational platform is the digital knowledge base "Ahead of Time." It includes materials corresponding to the department's various research areas, as well as to project-and-research work carried out by students and business teams (Figure 7). Students re-



Source: compiled by the authors.

Fig. 6. Structure of the Digital Simulator

port that it is highly effective for completing learning tasks that require non-standard solutions at the intersection of different subject areas.

The service not only enables users to obtain relevant information quickly and efficiently for the courses they are taking, but also helps them gather empirical data, expert opinion, and analytical materials for project work. This is achieved through dedicated search tools that allow materials to be filtered by thematic tags, resource type, author, and keywords in Russian, English, and Chinese.

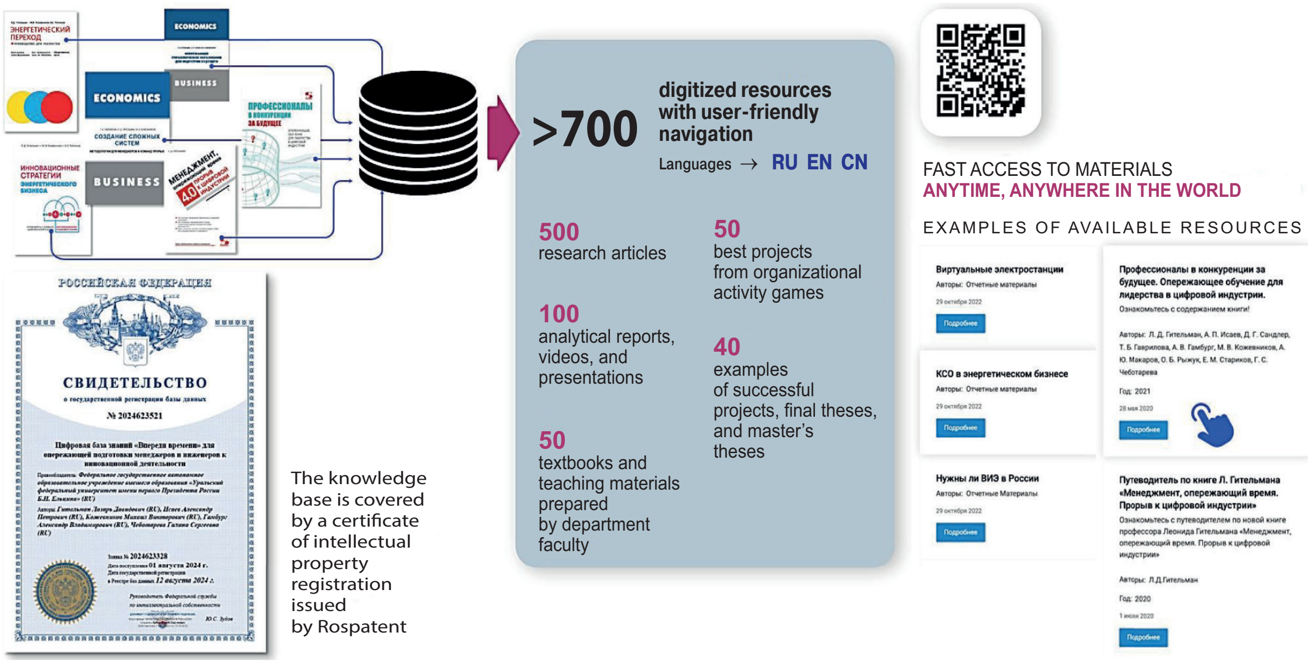
The distinctive features of the knowledge base are as follows:

– 95% of the resources have been prepared by department faculty;
– the content is specifically focused on developing students' engineering and economic competencies, above all systems thinking, and on helping them master the interconnections among engineering, technology, ecology, economics, finance, and management;
– all resources are aligned with specific courses within the department's educational offerings; targeted discipline-based searches greatly facilitate theoretical preparation and significantly improve the effectiveness of independent study;
– the service is adapted for international students: the menu and the key characteristics of resources, including titles, abstracts, and keywords, are available in both Russian and English, while some of the most important materials are also available in Chinese.

The knowledge base helps restructure the learning process by freeing up time for work on the most challenging issues facing a given industry or enterprise. This creates the conditions for a more progressive balance within the educational process: 20% discussion of problems, 25% research and analytics, 35% design, and 20% exposure to advanced practice.

The following forward-looking components of the platform are currently under development:

- Digital twins: full digital replicas of real production facilities in which each piece of equipment has its own economic model, including hourly operating cost, energy consumption, and depreciation; each material "knows" its own price and logistics parameters; and every decision is instantly translated into an economic outcome. Students can reconfigure the production process and immediately see how cash flow changes.
- AI assistants: intelligent agents embedded in every element of the platform. They analyze the history of decisions, forecast consequences, highlight risks, and propose alternatives. AI thus becomes more than a tool: it becomes a co-creator of solutions, expanding human cognitive capacity and enabling users to evaluate hundreds of times more scenarios than would be possible manually.
- An end-to-end digital trajectory: the platform records each student's digital footprint, including what decisions they made, what mistakes they made, and how quickly they learned to balance technology and



Source: compiled by the authors.

Fig. 7. Structure of the «Ahead of Time» Engineering and Economic Knowledge Base

economics. This becomes an objective portfolio that is clear and meaningful to employers. By looking at the student's learning trajectory, an enterprise can already understand whom it is hiring and what kinds of tasks can be entrusted to that person.

Thus, the department's platform becomes a full-fledged working environment in which users can find relevant information exactly when they need it, model the consequences of decisions in digital simulators before those decisions are made, and quickly connect with outside experts, colleagues, and instructors.

This is precisely the logic built into the architecture of the platform: to serve as a provider of tools through which specialists can, to a considerable extent, acquire the competencies they need on their own.

Conclusion

We believe the article has shown that contemporary engineering, economic, and management education is not aligned with the challenges the country now faces. The role of engineering and economic education is therefore becoming increasingly important. Without it, technological leadership will remain a slogan rather than an imperative for survival in an aggressively competitive environment. The problem has become acute and requires an immediate response.

The solutions proposed here affect a wide range of stakeholders, from students and university faculty to business employers and public authorities. They therefore call for broad discussion and a degree of consensus across both the academic and business communities.

With this in mind, the authors propose the following questions for discussion:

1. How can the engineering, economic, and humanities components of education be balanced so as to cultivate the culture and competencies required of a new generation of technological leaders?

2. What qualities and competencies should a university graduate possess in order to engage in breakthrough innovation suited to the era of digital technologies and AI?

3. How can interdisciplinarity, along with the corresponding tools and competencies, be implemented in practice under conditions of acute shortages of qualified instructors, digital laboratory infrastructure, and shared university–industry platforms for the experimental testing of new developments?

4. Should the mathematical component of education—and, in some cases, natural science training, especially in physics—be substantially strengthened, with corresponding changes to the entrance examinations required of applicants?

5. To what extent does engineering and economic training require a substantial—indeed, manyfold—increase in practical training, together with a move away from the overly formal approach still common in both universities and business? In the same vein, should engineering and economic issues relevant to real production be introduced from the first year and studied in conjunction with other disciplines, both theoretical and applied?

6. What organizational barriers might hinder the implementation of a new model of engineering and economic education?

7. How broadly applicable is the proposed educational model? Can it be used across different industries?

8. Would it be advisable to begin with pilot projects in anticipatory engineering and economic education, and what sequence of steps would be needed to scale up the resulting experience?

9. Is there now a need to include engineer-economist as an official degree track within the system of higher education specialties?

10. Finally, should the model of specialized engineering and economic faculties or institutes, as it existed in the Soviet period at the country's leading universities, be revived on a fundamentally new basis?

These may not be all the questions that arise for the reader. Yet the problem is so complex that both the range of issues and the answers to them may vary. We hope that constructive support for, or criticism of, the position advanced here will help generate sound solutions.

References

Gavrilova T.B., Gitelman L.D., Kozhevnikov M.V. (2017). *System Engineering for Manager*s. Moscow, Ekonomika. (In Russ.)

Gavrilova T.B., Gitelman L.D., Kozhevnikov M.V. (2024). *Creation of Complex Systems. The Fundamental Course of System Literacy*. Moscow, SOLON-Press. (In Russ.)

Gitelman L.D. (2020). *Management Ahead of Time. A Breakthrough to the Digital Industry*. Moscow, SOLON-Press. (In Russ.)

Gitelman L.D., Gavrilova T.B., Kozhevnikov M.V. (2024). Systems Literacy - A New Perspective for Innovation Managers and Engineers. *Strategic Decisions and Risk Management*, 15(2): 118-133. https://doi.org/10.17747/2618-947X-2024-2-118-133. (In Russ.)

Gitelman L.D., Isayev A.P., Kozhevnikov M.V., Gavrilova T.B. (2022a). Interdisciplinary Competencies of Managers for a Technological Breakthrough. *Strategic Decisions and Risk Management*, 13(3): 182-198. DOI: 10.17747/2618-947X-2022-3-182-198. (In Russ.)

Gitelman L.D., Isayev A.P., Kozhevnikov M.V., Gavrilova T.B. (2022b). Fundamental Knowledge and Flexibility of Thinking as Priorities of Management Education for Technological Breakthrough. *Strategic Decisions and Risk Management*, 13(2): 92-107. DOI: 10.17747/2618-947X-2022-2-92-107. (In Russ.)

Gitelman L.D., Kozhevnikov M.V. (2025). Results and Prospects of Reforms in the Electric Power Industry. Part 4: The Personnel Problem Requires an Immediate Solution. *Energetik (Power & Electrical Engineering)*, 9: 3-13. DOI: 10.71527/EP.EN.2025.09.001. (In Russ.)

Gitelman L.D., Kozhevnikov M.V., Isaev A.P. (2025). Results and Prospects of Reforms in the Electric Power Industry. Part 5: Engineering and Economic Project for the Realization of New Opportunities. *Energetik (Power & Electrical Engineering)*, 10: 3-13. DOI: 10.71527/EP.EN.2025.10.001. (In Russ.)

Gitelman L.D., Kozhevnikov M.V., Ratnikov B.E. (2023). *Energy Transition: A Guide for Realists*. Moscow, SOLON-Press. (In Russ.)

Gromova E.M., Berkutova D.I., Gorshkova T.A. (2025). STEM Education: Methodology and Career Guidance Opportunities. *Professional Education in Russia and Abroad*, 3: 146-152. (In Russ.)

Kravchenko S.I. (2025). Digital Transformation of Industry: Stable Drivers and Contextual Growth Factors. *Strategic Decisions And Risk Management*, 16(4): 350-360. DOI: 10.17747/2618-947X-2025-4-350-360. (In Russ.)

Loginov M.P., Usova N.V., Kukanova P.A., Alexeeva S.A. (2025). Artificial Intelligence Adoption: Drivers and Barriers to Development. *Strategic Decisions and Risk Management*, 16(3): 275-287. DOI: 10.17747/2618-947X-2025-3-275-287. (In Russ.)

Chentsova E.P., Chentsov M.S. (2023). Features of the Country's Innovative Development: China's Experience. *Issues of Innovative Economy*, 13(4): 1835-1853. (In Russ.)

Zhang Ya., Pecheritsa V.F. (2025). The Evolution and Logical Features of China's University Entrance Examination Policy after the Start of the Reform and Opening-up Policy. *Social and Humanitarian Knowledge*, 5: 394-398. (In Russ.)

Ahmed M., Araral E., Khan M. (2025). Barriers to Just Energy Transition: Institutional and Infrastructure Challenges in Developing Countries. *Sustainable Futures*, 10: 101414. DOI: 10.1016/j.sftr.2025.101414.

Bouchrika I. (2026). *Admission Requirements for Economics Degree Programs*. https://research.com/advice/admission-requirements-for-economics-degree-programs.

Fotis G., Maris T.I., Mladenov V. (2025). Risks, Obstacles and Challenges of the Electrical Energy Transition in Europe: Greece as a Case Study. *Sustainability*, 17: 5325. DOI: 10.3390/su17125325.

Heinberg R. (2022). T*he Renewable Energy Transition Is Failing*. https://www.resilience.org/stories/2022-11-22/the-renewable-energy-transition-is-failing/.

Ionescu A., Furdui R., Gavreliuc A., Greenfield P.M., Weinstock M. (2023). The Effects of Sociocultural Changes on Epistemic Thinking across Three Generations in Romania. *PLoS ONE*, 18(3): e0281785. DOI: 10.1371/journal.pone.0281785.

Phan H.P., Ngu B.H. (2021). A Perceived Zone of Certainty and Uncertainty: Propositions for Research Development. *Frontiers in Psychology*, 12: 666274. DOI: 10.3389/fpsyg.2021.666274.

Reynolds M. (2024). Systems Thinking Principles for Making Change. *Systems*, 12(10): 437. DOI: 10.3390/systems12100437.

Torralba J., Membrillo-Hernández J. (2025). Challenge-Based Learning Through Making: Representing STEM Crosscutting Concepts Through Designing and Making in Middle School Engineering. *Education Sciences*, 15: 1292. DOI: 10.3390/educsci15101292.

Uchman W., Jurczyk M., Ochmann J., Remiorz L. (2026). Sustainable Energy Transition Challenges: Limits to the Integration of Core Energy System Components - Reliability Perspective. *Energies*, 19: 1232. DOI: 10.3390/en19051232.

About the Authors

Lazar D. Gitelman
Dr. Sci. (Econ.), Professor, Professor, Department of Energy and Industrial Management Systems, Ural Federal University named after the first President of Russia B.N. Yeltsin (Ekaterinburg, Russia). Web of Science ResearcherID: AHB-8473-2022; Scopus Author ID: 55806230600.
Research interests: energy business in the electric power and heat power sectors, proactive management, organizational transformations, management education.
ldgitelman@gmail.com

Mikhail V. Kozhevnikov
Dr. Sci. (Econ.), Associate Professor, Head of the Department of Energy and Industrial Management Systems, Ural Federal University named after the first President of Russia B.N. Yeltsin (Ekaterinburg, Russia). Web of Science ResearcherID: AAB-6693-2020; Scopus Author ID: 55805368400; ORCID: 0000-0003-4463-5625.
Research interests: knowledge-intensive services, innovative industrial development, management education.
m.v.kozhevnikov@urfu.ru

作者简介

Lazar D. Gitelman
经济学博士，教授，俄罗斯联邦首任总统 B.N. 叶利钦命名乌拉尔联邦大学能源与工业企业管理系统教研室教授（俄罗斯叶卡捷琳堡）。
WOS Research ID: AHB-8473-2022；Scopus Author ID: 55806230600。
研究方向：电力与热力能源行业中的能源业务、前瞻性管理、组织变革、管理教育。
ldgitelman@gmail.com
Mikhail V. Kozhevnikov
经济学博士，副教授，俄罗斯联邦首任总统 B.N. 叶利钦命名乌拉尔联邦大学能源与工业企业管理系统教研室主任（俄罗斯叶卡捷琳堡）。
WOS Research ID: AAB-6693-2020；Scopus Author ID: 55805368400；ORCID: 0000-0003-4463-5625。
研究方向：知识密集型服务、工业创新发展、管理教育
m.v.kozhevnikov@urfu.ru

The article was submitted on 27.01.2026; revised on 09.02.2026 and accepted for publication on 15.02.2026. The authors read and approved the final version of the manuscript.
文章于 27.01.2026 提交给编辑。文章于 09.02.2026 已审稿。之后于 15.02.2026 接受发表。作者已经阅读并批准了手稿的最终版本。