

# INCREASING THE COMPETITIVENESS OF THE EDUCATIONAL ENVIRONMENT: A MODEL OF BACHELOR'S AND MASTER'S TRAINING IN NATURAL SCIENCES WITH ENGINEERING THINKING TO INCREASE REGIONAL DEVELOPMENT AND ACHIEVE SUSTAINABLE GROWTH

*AUMENTAR A COMPETITIVIDADE DO AMBIENTE EDUCACIONAL: UM MODELO DE FORMAÇÃO DE BACHARELADO E MESTRADO EM CIÊNCIAS NATURAIS COM PENSAMENTO DE ENGENHARIA PARA AUMENTAR O DESENVOLVIMENTO REGIONAL E ALCANÇAR O CRESCIMENTO SUSTENTÁVEL*

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## Abstract

Ongoing changes in modern education are focused on ensuring national security and technical sovereignty of many countries around the world. The priorities of training highly qualified engineering personnel for key sectors of the economy – industry, agriculture, construction, transport, and the social sphere – necessitate a qualitative transformation of all levels of the education system to increase the competitiveness of countries in the international arena. In this context, the study examines the problem of training natural science teachers with engineering thinking for the development of the economy and industry of Russia. Using document analysis and an expert survey

## Resumo

*As mudanças em curso na educação moderna estão focadas em garantir a segurança nacional e a soberania técnica de muitos países ao redor do mundo. As prioridades de formação de pessoal de engenharia altamente qualificado para setores-chave da economia — indústria, agricultura, construção, transporte e esfera social — exigem uma transformação qualitativa de todos os níveis do sistema educacional para aumentar a competitividade dos países na arena internacional. Nesse contexto, o estudo examina o problema da formação de professores de ciências naturais com pensamento de engenharia para o desenvolvimento da economia e da indústria da Rússia. Utilizando*



(assessment), a model for training bachelors and masters of natural sciences with engineering thinking was developed, aimed at increasing the level of regional development of education and achieving sustainable growth. The developed model focuses on integrating natural science, technical, and humanitarian knowledge and establishing their hierarchy, continuity, and complementarity. The priorities of Russian education relate to the creation of a system of continuous advanced engineering education (a combination of preschool, general, higher, and advanced education). Therefore, on the one hand, the developed model aims to train professionals who are ready to implement innovative educational scenarios of engineering pedagogy. On the other hand, the proposed model advances the competitiveness of the educational environment. The proposed model was developed based on the understanding of the development of engineering thinking in natural science teachers as a process consisting of four substantive blocks: the value-meaning block; the cognitive block; the block of regulatory norms; and the creative design block.

**Keywords:** Education. Economic Development. Teaching. Pedagogy.

*análise de documentos e uma pesquisa com especialistas (avaliação), foi desenvolvido um modelo para a formação de bacharéis e mestres em ciências naturais com pensamento de engenharia, com o objetivo de aumentar o nível de desenvolvimento regional da educação e alcançar um crescimento sustentável. O modelo desenvolvido se concentra na integração do conhecimento em ciências naturais, técnico e humanitário e no estabelecimento de sua hierarquia, continuidade e complementaridade. As prioridades da educação russa estão relacionadas à criação de um sistema de educação avançada contínua em engenharia (uma combinação de educação pré-escolar, geral, superior e avançada). Portanto, por um lado, o modelo desenvolvido visa formar profissionais prontos para implementar cenários educacionais inovadores de pedagogia da engenharia. Por outro lado, o modelo proposto promove a competitividade do ambiente educacional. O modelo proposto foi desenvolvido com base na compreensão do desenvolvimento do pensamento de engenharia em professores de ciências naturais como um processo que consiste em quatro blocos substantivos: o bloco de valor-significado; o bloco cognitivo; o bloco de normas regulatórias; e o bloco de design criativo.*

**Palavras-chave:** Educação. Desenvolvimento econômico. Ensino. Pedagogia.

## 1 INTRODUCTION

The focus of the research lies on the problem of developing engineering thinking in education. We proceed from the priorities of transforming engineering education as a driver of innovation to achieve the sustainable development of modern society (the Icheon Declaration, the UNESCO Engineering for Sustainable Development report) (UNESCO & ICEE, 2021). Amid the rapid development of high technologies, the accumulation of large amounts of data, and all-encompassing computerization and robotization, the new educational paradigm for the development of engineering thinking requires a revision of the goals and approaches to the design of integrated content, the forms and methods of its implementation, and the desired results.

This problem gives rise to the issue of diagnosing the development of engineering thinking. In this respect, Kamp (2016) highlights a number of qualities, including "creativity, communication, lifelong learning, social value, interdisciplinary thinking, and ambition, especially for engineering students" (p. 15). The need to transform the content of the training of natural science teachers with the goal of developing engineering thinking is emphasized in the studies of Ignatieva *et al.* (2023), who place an emphasis on the creation of system-cluster models.

The aim of the present study is to develop a model for the training of natural science teachers with engineering thinking in bachelor's and master's degree programs to increase the level of development of regional education and achieve sustainable growth.

To achieve the goal, the study solved the following objectives:

- to establish theoretical, methodological, and methodical grounds to develop the structure and content of the main professional educational programs in natural science in the context of developing engineering thinking among future teachers;
- to develop a structural model for designing the content of the main professional educational programs for natural science teachers in the context of developing engineering thinking;
- to develop the necessary tools and conduct an expert assessment of the effectiveness of the proposed model.

## 2 LITERATURE REVIEW

Analyzing publications relevant to the research problem, we find that the scientific community is developing productive discourse on the methodological and applied aspects of training teachers with engineering thinking as a precondition of the modern paradigm of engineering education (Guzanov & Fedulova, 2019; Ignatieva *et al.*, 2023; Pisareva & Tryapitsyna, 2025).

Shchedrovitsky (2003) views engineering thinking as a special type of activity of human consciousness – thought activity in the framework of the sociocultural paradigm of scientific knowledge, its distinctive features being creativity and creation. Expanding on the idea of the creative component of engineering thinking, Sazonova & Chechetkina (2007) define engineering thinking as "creative technical systems thinking" that focuses

on finding optimal creative solutions from the standpoint of developing technical systems. Schafer *et al.* (2024) stress that the process of creative engineering relates to collective creative activity, the creativity of all participants "involved in the process of creating a product" (*ibid.*, p. 296). It is productive to consider the phenomenon of "engineering thinking" in the context of engineering as a form of invention (research, design, and modeling) (Glazunov, 2018).

Most authors argue that engineering thinking is a convergence of natural science, technical, and humanitarian knowledge (Ignatieva *et al.*, 2023). Through this lens, engineering thinking is seen as a system with all its variety of connections and interdependencies of included subsystems, which rules out a highly specialized approach (Andriukhina *et al.*, 2023; Igolnik, 2018; Sazonova & Chechetkina, 2007). Of interest are the issues of interiorization of humanitarian knowledge into the professional worldview of engineering specialists (Altshuller, 2024; Bystrova, 2018).

Researchers Butenko, Durov, and Shapovalov propose the idea of developing engineering thinking in the format of evolving "relay education," uniting all stages of training, including students' active participation in engineering research (Butenko, 2011; Butenko *et al.*, 2014).

Studies actively discuss the issues of adapting the content of engineering education to technological and social changes that lead to the generation of new knowledge and the adjustment of curricula (Kolmos *et al.*, 2016; Malmqvist *et al.*, 2022), changing educational practice programs in educational institutions (Capobianco & Rupp, 2014). More and more ground is gained by a technological and instrumental methodology that incorporates the mechanisms and conditions for the development of engineering thinking: technologies for the development of cognitive structures in engineering design specialists (Hannah *et al.*, 2012); technological redesign of programs to incorporate active technologies (Shirens *et al.*, 2020); technologies to address complex and unstructured sustainability challenges (Kopnina, 2020; Malmqvist *et al.*, 2022).

Martínez Bravo *et al.* (2021) and Korchazhkina (2018) argue for the need to build the digital competencies of engineering students. Mustafina *et al.* (2011) distinguish three levels of development of engineering thinking, reflecting the degree of readiness to apply technical knowledge in practice, from the reproductive to the design level.

Importantly, most experts note the inconsistency of the development of engineering thinking in students of technical and pedagogical universities, where general technical training is not an end in itself (Guzanov & Fedulova, 2019; Kondratiev & Ivanov, 2014; Kuznetsova, 2018; Vaulin *et al.*, 2024). Thus, despite reflecting the general trends, the training of natural science teachers with engineering thinking has its qualitative peculiarities.

Studies further highlight the complementarity of the integrative processes of developing teachers' engineering thinking based on engineering and pedagogical knowledge and professional pedagogical experience. Guzanov & Fedulova (2019), citing the work of Kudryavtsev & Yakimanskaya (1964), emphasize the similarity of pedagogical and engineering thinking, noting several common features, which include "a qualitative character, a probabilistic approach, a practical-transformative orientation, functionality, empiricity, and a behavioral understanding of the world." These commonalities make it possible to integrate the two types of thinking into a single system and consider it as a special type of the teacher's professional thinking. Such a synthesis involves developing and implementing up-to-date didactic models in the educational process of pedagogical universities, effectively training teachers with engineering thinking, designing the content of training courses based on informed decisions, analyzing this training, reflection, and meta-cognition (Guzanov & Fedulova, 2019).

Shapkin & Merkushev (1988) introduced the concept of "pedagogization of technical knowledge," where, along with the adaptation of technical knowledge to learning processes, "the process and result of incorporating pedagogical elements into technical content and their integration at the substantive and procedural levels" is considered (p. 43).

Relevant to our research is the position of Kislov, Korolev, Feoktistov, Shapko, and other researchers on the social mission of the teacher – familiarization with engineering culture and the development of students' engineering thinking (Feoktistov *et al.*, 2023; Korolev & Parshukova, 2023).

When designing the structure and content of training natural science teachers with engineering thinking, it is crucial to identify, methodologically substantiate, and ensure the integration of natural science, technical, and humanitarian knowledge and to establish their hierarchy, continuity, and complementarity, which requires dedicated research.

### 3 METHODOLOGY AND METHODS

#### 3.1 Methodology

To achieve the research goal, we developed a structural model for designing the content of bachelor's and master's degree training of natural science teachers with engineering thinking in specialty 44.03.05 Pedagogical education (with two training profiles), (the Core of Higher Professional Education), profile "Biology and Chemistry", and the Master's degree program "Innovation in natural science education", specialty 44.04.01 Pedagogical education (Figure 1).

The theoretical and methodological basis was comprised of universal strategic approaches and the principles developed by leading specialists at the Research Center for Strategic Pedagogical Studies of Minin University in the framework of this project (Loshchilova & Vinokurova, 2025; Vinokurova *et al.*, 2025). The main approaches included the cultural-worldview, transdisciplinary, synergistic, integral-situational, contextual, competency, convergent, and constructive-activity approaches.

The leading role is played by the cultural-worldview approach (Vinokurova *et al.*, 2025), which interacts with others and integrates them based on complementarity. This approach enriches the category of "engineering thinking" with co-evolutionary-value worldview orientations, focusing on including the ideas of co-evolution, rational nature management, biosphere compatibility, etc. This approach qualitatively changes the content of natural science disciplines, determining the role of engineering thinking in maintaining the stability of their functioning and ensuring the technological safety of the country.

The transdisciplinary approach consists in the development of transdisciplinary content through the synthesis of natural science, humanitarian, and technical knowledge, which implies reaching the level of transprofessionality.

The synergistic approach brings to the fore the use of human-scale models of cognition and the implementation of new content in the framework of cooperation and constructive dialogue.

The integral-situational approach offers various types of integration of the content of natural, humanitarian, and technical sciences. It involves the selection and structuring

of content through the morphostructural and functional integration of scientific knowledge in tune with the stylistic attitudes and characteristics of engineering thinking (Vinokurova *et al.*, 2025).

The contextual approach focuses on the use of contextual learning and builds connections between the obtained theoretical knowledge and future professional practice.

The convergent approach involves the synthesis of scientific and technological knowledge in the process of training natural science teachers with engineering thinking and the incorporation of the provisions of converged technologies (NBIC technologies) into the content to comprehend, analyze, and assess risks, opportunities, and prospects, including for the development of engineering thinking.

The competency approach defines the result of the development of engineering thinking based on the assimilation and comprehension of the content by students.

The constructive-activity approach determines the selection and structure of the content, considering the involvement of future teachers in various design practices that provide for the development of engineering thinking as part of specially organized productive and creative activities.

The examined approaches shaped the principles of designing the content of training for natural science teachers with engineering thinking: cultural relevance, systemic action, subjectivity, integration, systemic nature, coherence, complementarity, fundamentality, interdisciplinarity, reflection, continuity, dialogic nature, and the connection of theory and practice.

### **3.2 Research stages and methods**

The scientific search was carried out based on the analysis of publications on the research problem over the past 10 years in the eLibrary and Scopus databases. The methodological basis for designing the structure and content of the training of natural science teachers with engineering thinking comprised universal strategic approaches: cultural-worldview, transdisciplinary, synergistic, integral-situational, contextual, competency, convergent, and constructive-activity.

The developed content for the training of natural science teachers with engineering thinking was tested via the expert assessment method. Experts for the

assessment were recruited from the pedagogical research community. Expert selection criteria were as follows: 1. having a doctoral/candidate degree in pedagogical sciences; 2. having at least 5 years of teaching experience in a higher education institution; 3. having publications relevant to the subject of the study. In total, the assessment included 26 experts from nine universities of the Russian Federation: Blagoveshchensk State Pedagogical University, Volgograd State Pedagogical University, Ulyanovsk State Pedagogical University, Herzen State Pedagogical University of Russia, Moscow Pedagogical State University, Kazan Federal University, Evseviev Mordovian State Pedagogical University, Vyatka State University, National Research Lobachevsky State University of Nizhny Novgorod.

The initial expert assessment was carried out in 2025. The assessment consisted of several stages: 1) determining the expert assessment procedure and processing the results, developing an expert assessment chart; 2) selecting experts and informing them about the assessment procedure; 3) familiarizing experts with the expert assessment chart and organizing expert assessment; and 4) processing, interpretation, and reporting of the obtained data.

#### **4 RESULTS**

The structuring of content embodies the principle of complementarity. On the one hand, enrichment of the content of basic module disciplines is enriched with the basic professional educational program (BPEP), the Core of Higher Education, profile "Biology and Chemistry." On the other hand, we propose to introduce the end-to-end module "Theory and methodology of developing engineering thinking in students" into the structure of educational programs and the "Engineering Pedagogy" module into the master's program "Innovation in natural science education."

**Figure 1**

*Structural model for designing the content of pedagogical education*

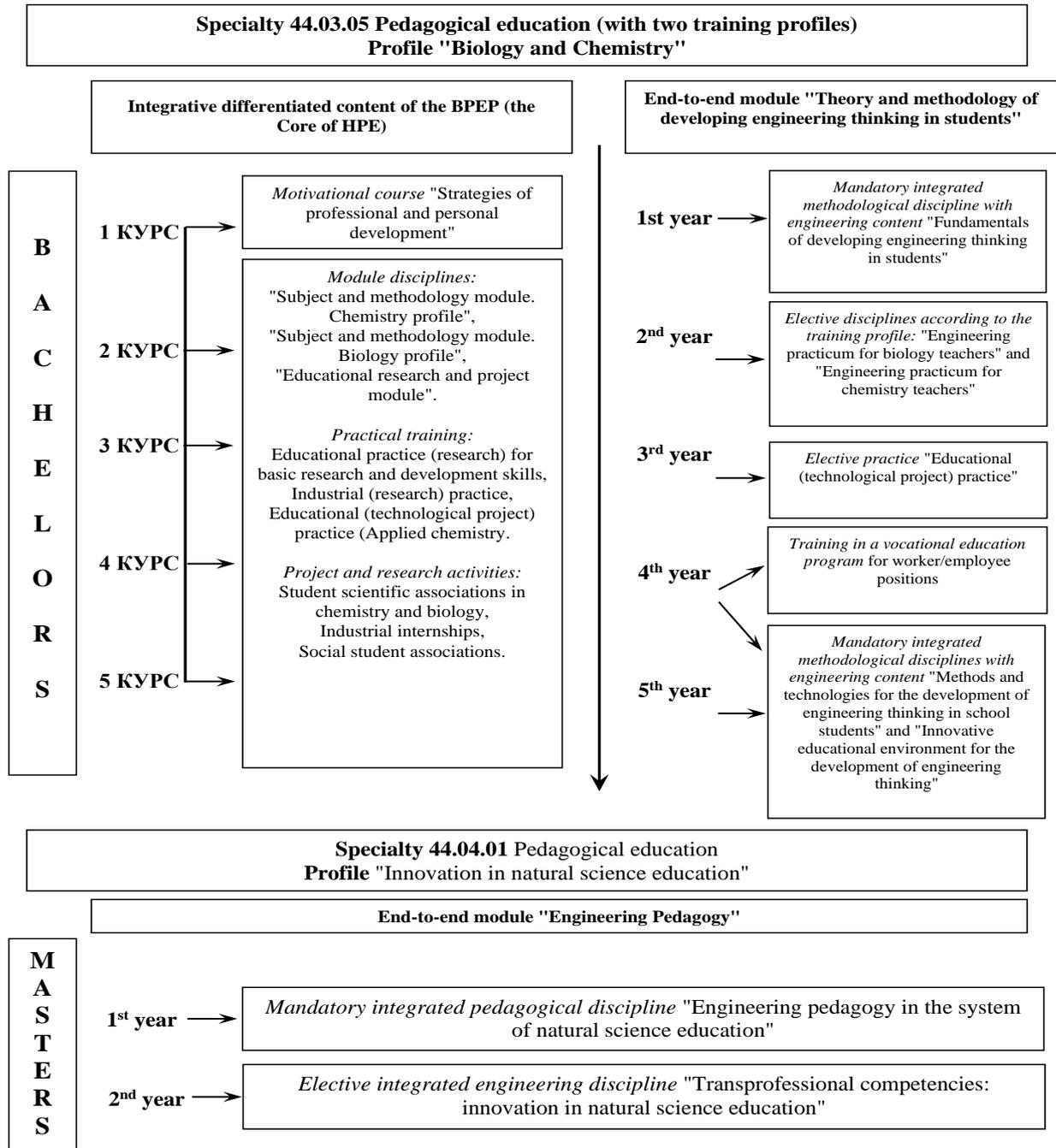


Table 1 shows the content elements of the training of teachers with engineering thinking based on the example of individual disciplines in the curriculum for specialty 44.03.05 Pedagogical education (with two training profiles) (the Core of Higher Professional Education), profile "Biology and Chemistry."

**Table 1**

*Content subjects in the training of natural science teachers with engineering thinking*

Year	Module	Disciplines/practicums	Content developing engineering thinking in future teachers
1st year		Strategies of professional and personal development	Russia's technological sovereignty for the country's stable and secure future. Engineering thinking as a prerequisite for technological sovereignty. The role of the natural science teacher in developing students' engineering thinking. Cognitive value attitudes for the development of engineering-type thinking. Development of the motivational project "Engineering professions through the eyes of a teacher."
2nd year	Digital communication module	Digital education technologies	Digital engineering technologies. Software products for design, engineering, invention: CAD systems (Computer-Aided Design), CAE systems (Computer-Aided Engineering), CAE systems (Computer-Aided Engineering), and information storage systems. Internet of Things technologies, etc. Virtual simulation of chemical technological and biotechnological processes.
3rd year	Subject and methodology module. Chemistry profile	Applied chemistry	Theoretical foundations of chemical technologies. Sulfuric acid production. Ammonia production. Nitric acid production. Production of mineral fertilizers: ammonium nitrate, sylvinit, and superphosphates. Glass production. Ceramic brick production. Iron production. Steel production. Natural gas treatment. Alcohol production. Ester production. Polyethylene production.
4th year		Modern technologies in chemistry education	Methodology and methods of studying modern chemical production technologies. Methodology for conducting a set of laboratory works by stages of chemical and technological processes. Development of team projects to create virtual layouts of chemical production facilities (elective).
4th year		Educational (familiarization) practice (physicochemical analysis methods)	Excursions to chemical industrial enterprises and research and design institutes. Identification of chemicals and materials using physical and chemical analysis methods in laboratory and production conditions (at the set place of practice).
5th year		Educational (technological project) practice (Applied chemistry)	Study of chemical processes at chemical enterprises. Project work commissioned by the enterprise to solve real technological problems.
2nd year	Subject and methodology module. Biology profile	Microbiology and basic virology	Principles of genetic design and optimization of biosystems. Biological design. Biological measurement devices (biomonitoring). Principles of molecular engineering and biosecurity. Microbiological production. Computational methods in biotechnology.
4th year		General ecology	Creation of biological cleaning systems. Principles of resource-saving technologies. Simulation of closed ecological life support systems. Design of biological monitoring systems. Principles of bioconversion and optimization of microbial processes. Environmental rehabilitation projects.

5th year		Solving the professional problems of a biology teacher	Planning and organization of the educational space for biotechnological processes. Creating holistic educational bioengineering products. Transforming complex industrial processes into accessible educational experiments.
5th year		Educational technologies in biology education	Design of training simulations of bioreactors and enzymatic processes. Principles for creating educational content to mimic real biotech systems. Visualization of cloning and gene expression using virtual reality. Creating digital models of living systems in bioengineering.
3rd year	Educational research and project module	Research and development methods	Goal setting, development of scientific and technological experiments, planning work on the technical project, description of the product of the project.
3rd year		Educational practice (research)	Research methods and techniques. Features of goal setting in engineering technology projects. Engineering design development. Planning experimental work in engineering.
3rd year		Industrial (research) practice	Implementation of research projects with an engineering component at the request of employers.

Table 2 presents the content of the "Theory and methodology of developing engineering thinking in students" module for bachelor students in natural science, which is studied throughout all 5 years of study. This module includes mandatory disciplines, which are taken by all training profiles, and elective disciplines, which are developed individually for each profile.

**Table 2**

*Content of the integrative module "Theory and methodology of developing engineering thinking in students"*

Year	Disciplines/practicums	Content
1st year	Fundamentals of developing engineering thinking in students	Theoretical and methodological foundations of engineering thinking. Retrospective analysis of the problem. Approaches and principles for the development of engineering thinking. Universal worldview components in engineering thinking. Ethical aspects of engineering thinking. Models of integrating technical, natural science, and humanitarian knowledge. Subjects of engineering thinking.
2nd year	Engineering practicum for biology teachers	Bioengineering and nanobiotechnology. Bioengineering ethics. Development of software to simulate ecological and biotechnological processes. Creating models of industrial bioreactors for school laboratories. Design methods for integrated zero-waste production systems.
2nd year	Engineering practicum for chemistry teachers	Creation of models of experimental installations and instruments for the production of chemicals and materials. Development of software for modeling chemical processes. Methods of designing chemical technological systems of zero-waste production.

3rd year	Educational (technological project) practice	Development of engineering thinking in future natural science teachers through "immersion" in scientific research. Design and implementation of research projects with an engineering component.
4th year	Methods and technologies for the development of engineering thinking in school students	Technologies and methods for the development of engineering thinking, including the technologies of team interaction, project, experimental and design activities in the formats of game techniques, fab labs, STEAM technologies, nano-bio-info-cognitive technologies, practicums, programming, the use of metacognitive and contextual technologies, integrated problem situations, the engagement of students in solving engineering and research problems, and the organization of creative design activities for students, and TRIZ and ARIZ technologies.
5th year	Innovative educational environment for the development of engineering thinking	Design of an innovative educational environment for the development of engineering thinking. Worldview-value-goal, content, and technological aspects of designing an innovative educational environment for the development of engineering thinking. Components of an innovative educational environment for developing engineering thinking. Cooperation between the external and internal environment. Introduction of professional education platforms in the design of a new educational environment.

Table 3 shows the content of the "Engineering Pedagogy" module for master's students in specialty 44.04.01 Pedagogical education, Master's degree program "Innovation in natural science education".

**Table 3**

*Contents of the "Engineering Pedagogy" module in specialty 44.04.01 Pedagogical education*

Year	Disciplines/practicums	Content
1st year	Engineering pedagogy in the system of natural science education	Theoretical fundamentals of engineering pedagogy. Fundamentals of teaching engineering and natural science. Development of educational programs and educational materials with engineering content. Monitoring and assessing the effectiveness of engineering pedagogy. Methodological foundations of integrating engineering disciplines into the system of natural science education.
2nd year	Transprofessional competencies: innovation in natural science education	Modern approaches to the teaching profession in a post-industrial society. The concept of transprofessional competencies combining hard, soft, and digital skills. Transprofessional competencies in the training of natural science teachers. Diagnostics and assessment of the effectiveness of transprofessional competency development.

In the design of the content of training for natural science teachers with engineering thinking, particular importance is assigned to students' research and project

work based on modern laboratory complexes, the Technopark of universal pedagogical competencies, and the Pedagogical quantorium. Pedagogical university students can conduct engineering research in the framework of student scientific associations based on design bureaus, scientific laboratories, the facilities of partnering training and production centers, etc.

## 5 EXPERT SURVEY

The expert opinions of the scientific and pedagogical community on the developed model for designing the content of training bachelors and masters with engineering thinking were established through the analysis, generalization, and interpretation of the results of the expert assessment. A summary table was compiled using the materials of the expert opinions (Table 4).

**Table 4**

*Summary table of the results of the expert assessment of the structural model for training Bachelors and Masters of natural sciences with engineering thinking*

No.	Expert assessment indicators	Average score (on a 5-point scale)
1.	Relevance of the proposed model	5.0
2.	Compliance of the model structure and content with the target landmarks identified in the study	4.8
3.	Theoretical and methodological basis of the model: validity and sufficiency	4.7
4.	Representation and sufficiency of the volume of all structural components of the content (ontological-cognitive, axiological, activity)	4.6
5.	Originality of the end-to-end integral module (bachelor's and master's degrees) and the content of its curricula and their compliance with research objectives	4.7
6.	Assessment of the prospects for replication of the model in the practice of pedagogical universities	4.7
7.	<b>Overall average score for all indicators</b>	<b>4.75</b>

## 6 DISCUSSION

The results reveal that experts describe the relevance of the proposed model as high. Assessing the theoretical and methodological basis of the model, all experts confirmed its completeness, validity, and consistency with research goals and objectives.

Expert analysis of the choice and structure of the content ensuring the development of students' engineering thinking concluded on its sufficiency and coherence. Most experts had a positive impression of the end-to-end integrated module presented in the model, noting that it adds a transprofessional vector to the training of future teachers.

The novelty and practical orientation of the conducted research caused no doubt among the experts.

Nevertheless, experts made proposals to enhance the individualization of the process of developing engineering thinking based on the developed content and to include components that would appeal to students' emotions. It was also proposed to enable the inclusion of some region-specific content in the end-to-end module for bachelors and masters in natural science with engineering thinking.

Thus, most experts gave positive assessments of the developed model, noting a wide range of opportunities for the effective development of engineering thinking among future natural science teachers, and recommended it to be implemented after the suggested revision. The recommendations obtained from the expert assessment were taken into consideration to clarify and edit the developed model for increasing the competitiveness of the educational environment and achieving sustainable growth.

Technical knowledge and skills can be obtained by teachers in vocational education programs (VEPs) for workers/employees. In particular, the results of the study were implemented in practice as part of a VEP under the Priority 2030 strategic academic leadership program at the "My First Profession" training center of Minin University in the engineering technology profile "Chemical analysis lab technician, 4th grade." The VEP was developed in accordance with the demands of regional industrial enterprises. In the 2024-2025 academic year, the program was implemented in partnership with the NORCHEM Group.

## **7 CONCLUSIONS**

The task of increasing the competitiveness of the educational environment is tied to the problems of developing a model for designing the structure and content of the main bachelor's and master's vocational educational programs in natural sciences in the context of developing engineering thinking.

The study presented a structural model for designing the training content for teachers with engineering thinking. This model ensures the complementarity of "enrichment" of invariant content under the concept of "the Core of Higher Pedagogical Education" and the end-to-end integrative module "Theory and methodology of developing engineering thinking in students" (bachelor's degree) and the "Engineering Pedagogy" module (master's degree). The presented model takes into account regional specifics but can be adapted for use in other regions, taking into account the specifics of the curriculum.

The results of the study could be of value to teachers, administration, graduate students, and students at pedagogical universities. The findings can be used in designing methods to develop engineering thinking in natural science teachers, in developing educational and methodological materials, educational modules, and advanced vocational education programs, and in building mechanisms for interaction between the scientific, pedagogical, and industrial communities.

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### **Authors' Contribution**

All authors contributed equally to the development of this article.

### **Data availability**

All datasets relevant to this study's findings are fully available within the article.

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