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DEVELOPING THE LOGICAL THINKING OF FUTURE ENGINEERS BASED ON THE MODELING OF PROBLEMATIC REAL-LIFE SITUATIONS

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Annotation: In engineering education, the application of theoretical knowledge in practical situations, the analysis of complex problems, and the making of evidence-based decisions are important factors determining the professional readiness of future specialists. This article examines the didactic possibilities and methodological model for developing logical thinking in future engineers based on modeling real-life problem situations.

Key words: future engineer, logical thinking, problem-based learning, life situation, modeling, engineering education, reflective thinking, professional competence.

Annotatsiya. Muhandislik ta’limida nazariy bilimlarni amaliy vaziyatlarda qo‘llash, murakkab muammolarni tahlil qilish va dalillarga asoslangan qarorlar qabul qilish bo‘lajak mutaxassislarning kasbiy tayyorgarligini belgilovchi muhim omillardan hisoblanadi. Mazkur maqolada hayotiy muammoli vaziyatlarni modellashtirish asosida bo‘lajak muhandislarning mantiqiy tafakkurini rivojlantirishning didaktik imkoniyatlari va metodik modeli ko‘rib chiqildi.

Kalit so‘zlar: bo‘lajak muhandis, mantiqiy tafakkur, muammoli ta’lim, hayotiy vaziyat, modellashtirish, muhandislik ta’limi, refleksiv fikrlash, kasbiy kompetensiya.

Аннотация: В инженерном образовании важными факторами, определяющими профессиональную готовность будущих специалистов, являются применение теоретических знаний в практических ситуациях, анализ сложных проблем и принятие решений на основе фактических данных. В данной статье рассматриваются дидактические возможности и методологическая модель развития логического мышления у будущих инженеров на основе моделирования реальных проблемных ситуаций.

Ключевые слова: инженер будущего, логическое мышление, проблемно-ориентированное обучение, жизненные ситуации, моделирование, инженерное образование, рефлексивное мышление, профессиональная компетентность.

Introduction. Modern engineering practice is characterized by the increasing complexity of technical systems, the automation of production processes, and rising demands placed on technological solutions. In an engineer’s professional work, logical thinking enables the identification of relationships between data, the understanding of the operational mechanisms of technical processes, the verification of evidence, and the formulation of well-founded conclusions. Logical analysis is particularly significant when diagnosing technical malfunctions, optimizing energy consumption,

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enhancing production efficiency, and selecting design solutions. However, these skills are not developed merely by absorbing existing knowledge; rather, they are cultivated through a student's independent inquiry and active engagement with challenging, problem-oriented situations.

LITERATURE REVIEW AND METHODS.

The objective is to develop a methodological model aimed at fostering the logical thinking of future engineers through the modeling of real-life problematic situations, and to provide a theoretical substantiation for its components.

Based on the research objective, the following tasks have been defined:

1. To analyze pedagogical and methodological approaches to developing logical thinking within engineering education.
2. To identify the didactic potential of modeling real-life problematic situations.
3. To define the stages and components of a methodological model focused on the development of logical thinking.
4. To propose criteria and indicators for evaluating student performance.
5. To develop methodological recommendations for the practical application and empirical verification of the model.

Logical thinking, problem-solving, and experience-based learning have been studied within various theoretical frameworks in pedagogy and educational psychology.

An analysis of the literature indicates that theoretical arguments alone are insufficient to draw conclusions regarding the effectiveness of a developed methodological model. Such conclusions must be verified through appropriate learning tasks, assessment tools, and empirical data.

The theoretical foundation of this research consists of the substantive analysis, comparison, and synthesis of scientific literature, as well as the systematization of pedagogical concepts. The analysis focuses on the interrelationships between the concepts of logical thinking, problem-solving, modeling, experiential learning, and reflective activity.

Principles for Developing the Methodological Model

The proposed model is based on the following principles:

- Professional orientation: Learning situations must be substantively aligned with problems likely to be encountered in engineering practice.
- Problem-centeredness: Tasks should require analysis and independent inquiry rather than the mere reproduction of pre-existing answers.
- Systematic approach: The stages—from identifying a problem to verifying the outcome—are organized as an interconnected process.
- Evidence-based reasoning: Every solution must be substantiated by relevant calculations, observations, or logical arguments.
- Reflexivity: Students engage in the re-analysis of their own thought processes and the decisions they have made.
- Transparency of assessment: Indicators of logical thinking are evaluated based on pre-established criteria.

Logical thinking assessment criteria

Five key criteria are proposed for assessing students' logical thinking: problem comprehension, analytical reasoning, model construction, justification of the solution, and reflective evaluation. Each criterion is defined by specific, observable indicators. For instance, problem comprehension can be

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assessed by how well a student identifies the core conditions of a task and determines unknown elements; analytical reasoning can be evaluated by how they compare factors and establish cause-and-effect relationships.

As a practical assessment tool, a rubric with a 0–3 point scale for each criterion is suggested. In this system, 0 points indicate that the skill is not demonstrated; 1 point signifies that the skill is shown only with significant assistance; 2 points indicate that the skill is performed largely independently; and 3 points denote that the skill is demonstrated consistently, independently, and based on evidence. This scale serves as a methodological instrument proposed in this article; its reliability and validity require separate verification.

RESULTS AND DISCUSSIONS.

As a result of a theoretical-methodological analysis, a six-stage methodological model was proposed, designed to develop the logical thinking of future engineers through the modeling of real-life problematic situations. The model begins with an introduction to a problematic situation and concludes with a reflective assessment of the results obtained.

Structural Stages of the Methodological Model

First stage — understanding the problem. The student becomes familiar with a situation closely resembling real life or industrial practice, identifies the core problem, and determines the conditions of the task. At this stage, relevant questions are formulated to prevent any misinterpretation of the problem.

Second stage — analyzing data. The student sorts through available information, distinguishes between primary and secondary factors, identifies missing data, and formulates potential causes.

Third stage — creating a situational model. The problem is represented using a mathematical expression, algorithm, drawing, flowchart, cause-and-effect diagram, or computer simulation. The model must retain the essential characteristics of the real-world situation and reflect the hypotheses to be tested.

Fourth stage — developing alternative solutions. The student proposes several potential solutions, compares them based on established criteria, and identifies the limitations of each option.

Fifth stage — verifying the solution. The chosen solution is tested through calculations, simulations, re-analysis of existing data, or a safe educational experiment. If necessary, the model is revised.

Sixth stage — reflective evaluation. The student explains the logical basis for their decision, identifies which assumptions were significant, and points out the limitations of the model. The final conclusion reflects not only the result but also the reasoning process that led to it.

An important feature of this model is that its stages are not strictly linear. If new information emerges while evaluating a solution, the student can return to previous stages to modify initial assumptions or the model itself. This characteristic aligns with the dynamic and multifactorial nature of engineering problems.

The model’s connection to components of logical thinking

The proposed model views logical thinking not as a single, indivisible ability, but as a set of complementary skills. Analytical thinking manifests through breaking down a problem into its constituent parts and identifying key factors; cause-and-effect reasoning is demonstrated by examining the links between potential causes and observed outcomes. Algorithmic thinking involves establishing a sequence for problem-solving and organizing the necessary steps. Evaluative thinking encompasses

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comparing alternatives based on specific criteria, verifying that conclusions are supported by evidence, and recognizing the limitations of decisions.

Evaluation criteria and indicators

Table 1. Logical thinking assessment criteria

Criterion	Home indicators
The problem understanding	The problem clear to express, to express conditions separation, unknown factors designation
Analytical thinking	Data sorting, factors comparison, cause and effect their connections search
Model creation	The situation scheme, algorithm or mathematician in the expression reflection to hold
Solution justification	Alternative options comparison, evidence to bring, to choose explanation
Reflexive assessment	The result check, errors identify model constraints explanation

In the proposed rubric, each of the five criteria is scored on a scale of 0–3 points, resulting in a total score ranging from 0 to 15. However, the thresholds for categorizing scores as "low," "medium," or "high" should not be established as an initial methodological suggestion; rather, they should be determined following a separate validation process.

This form of assessment allows the instructor to identify not only the student's final answer but also their strengths and areas requiring further development within the problem-solving process.

Example of implementing the methodological model in practice

To illustrate the practical application of the model, consider a hypothetical scenario involving an increase in electricity consumption at a manufacturing plant.

Students are provided with data regarding the capacity of production equipment, operating hours, production volume, and energy consumption. Their task is to identify factors that may have contributed to the rise in energy consumption and to develop a well-founded proposal for reducing it. First, students define the core problem within the scenario. Then, by analyzing the available data, they formulate hypotheses—for instance, regarding excessive equipment operation, changes in load patterns, or issues related to the technical condition of the equipment. In the next stage, the relationship between energy consumption and the operating mode is expressed in the form of a model. Subsequently, students compare alternative solutions—such as optimizing equipment operating time, improving maintenance, or selecting a more efficient operating mode. The economic and technical constraints of each option are examined. Finally, the chosen solution is verified through calculations or simulations, and the conditions for its implementation are explained.

This example illustrates how the methodological model is structured; however, it is not the result of an actual pedagogical experiment. To draw conclusions regarding changes in students' logical thinking, it would be necessary to implement this task in practice and to measure and compare the results against predetermined criteria.

Discussion. The theoretical significance of the proposed methodological model lies in its integration of problem-based learning, modeling, and reflective thinking into a cohesive sequence of educational activities. At the core of the model is not the acquisition of a ready-made solution, but rather a process that encompasses understanding a problem, articulating it, testing potential solutions,

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and evaluating the outcomes. Furthermore, a distinctive methodological feature of this model is that the assessment of logical thinking is integrated into every stage of the learning task.

In engineering education, the practical advantage of this approach lies in its ability to align academic assignments with professional tasks. Students simultaneously apply theoretical knowledge, account for technical constraints, and analyze the consequences of their decisions. However, the mere presence of a professional context does not automatically guarantee deep thinking. Assignments must require students to interpret data and justify alternative options, rather than simply replicating a pre-existing algorithm.

Conclusion. Modeling real-world problematic situations is a promising methodological approach—both theoretically and practically—for developing the logical thinking of future engineers. This article proposes a six-stage methodological model grounded in theoretical perspectives on problem-based learning, experiential learning, step-by-step problem-solving, and reflective thinking.

The model encompasses the following processes: understanding the problem, analyzing data, modeling the situation, developing alternative solutions, verifying the chosen solution, and reflectively evaluating the outcomes. This sequence enables the integration of analytical thinking, the identification of cause-and-effect relationships, algorithmic approaches, and evidence-based decision-making within engineering assignments. The methodological contribution of this article lies in the systematization of activity stages aimed at developing logical thinking, as well as the criteria and indicators used to evaluate them. The proposed assessment rubric serves as a primary tool for monitoring not only the student's final outcome but also their underlying thought process.

However, the effectiveness of the model proposed in the article has not yet been verified through empirical experimentation. Consequently, future research should focus on practically testing the model within engineering disciplines, measuring changes in logical thinking indicators, and determining the reliability of the assessment tools.

Overall, an educational approach based on modeling real-life problem situations offers a methodological framework for connecting engineering knowledge with practical application, supporting independent student inquiry, and preparing students to make well-founded decisions in complex professional scenarios.

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