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ORGANIZING A PROBLEM-BASED LECTURE ON THE FUNDAMENTALS OF THERMODYNAMICS

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ABSTRACT

This article presents a model for organizing a problem-based lecture on the fundamentals of equilibrium and non-equilibrium thermodynamics in higher education institutions. The discussion focuses on selecting core problems for the topic and constructing a system of auxiliary problem-solving questions.

The study emphasizes that structuring lectures around problem-solving approaches fosters students' critical thinking, creative exploration, and practical problem-solving skills. The analysis highlights opportunities to enhance student engagement in the learning process through problem-based scenarios.

Keywords: problem-based lecture, problem-solving scenario, process direction, thermodynamic equilibrium, entropy, dissipative structures.

INTRODUCTION

The integration of innovative pedagogical technologies into the educational process to improve quality and efficiency is one of the most pressing challenges of our time. In the 20th century, the concept of problem-based learning rapidly gained traction and became widely adopted in education.

Practical experience shows that students often struggle with direct problem-solving due to a lack of independent research skills and critical thinking abilities. Therefore, organizing problem-based lessons is crucial for developing students' capacity to analyze real-world challenges and creatively seek solutions. This approach enhances their ability to manage cognitive activities and aligns the learning process with creative exploration.

Physics serves as a foundational discipline for all technical fields. Consequently, problem-based organization of physics lessons helps future specialists in engineering and technology develop the skills needed to address practical technical challenges they may encounter.

The primary objective of problem-based teaching is to cultivate students' creative exploration and independent thinking skills. One of the active learning methods is the problem-based lecture.

The issue of individual engagement in learning is a significant concern in psychology, pedagogy, and educational practice. Educators frequently note students' lack of interest, motivation, and curiosity in learning, prompting efforts to employ effective teaching methods, forms, and models. Increasing learner engagement is of paramount importance.

This article addresses the organization of problem-based lessons in physics for higher technical education institutions. It examines the challenges of structuring problem-based lectures on classical and modern thermodynamics.

MAIN SECTION

In problem-based teaching, the instructor must systematically create problem-based scenarios, organize students' problem-solving activities during lessons, and ensure their independent work aligns with existing knowledge. A problem-based scenario serves as the core element of problem-based teaching, fostering new ideas, stimulating students' desire to learn, and activating their thinking.

When planning the problem-based study of a topic or section, it is essential to consider:

- The content and characteristics of the material,
- Its difficulty level,
- The nature of the information.

Based on students' reasoning and observational abilities, a structured set of tasks or questions is developed to identify contradictions in the learning process. These tasks may include:

1. **Questions requiring explanations of specific phenomena.**
2. **Questions prompting students to compare or contrast existing ideas or diverse viewpoints on a phenomenon.**
3. **Tasks aimed at comparing and analyzing ideas or conclusions.**

Developing and applying a logical sequence of problem-based scenarios or questions is fundamental to organizing problem-based teaching. A well-structured system of problem-based questions includes:

- A **central problem-based question**,
- A series of **supporting auxiliary questions**.

Identifying the central problem-based question, though challenging, enhances students' cognitive engagement and enriches the learning process.

Problem-Based Lectures and Active Learning

A problem-based lecture transforms the learning process into an investigative activity. Its success depends on collaborative interaction between the instructor and students. The lecturer's role extends beyond delivering information—it involves engaging listeners in recognizing objective contradictions in the subject matter and exploring solutions.

Through collaboration with the instructor, students **"discover" new knowledge** and grasp the theoretical aspects of their specialization or specific disciplines.

Key Differences from Traditional Lectures

A problem-based lecture fundamentally differs from a traditional lecture in its logical structure:

- In a **traditional lecture**, information is presented as predefined material for memorization.
- In a **problem-based lecture**, new knowledge is introduced as **unknown**, requiring students to actively participate in discovery rather than passively absorb or reproduce information.

Core Didactic Method: Problem-Based Scenarios

The primary didactic tool in problem-based lectures is the **creation of problem-based scenarios**. These scenarios:

- Present a **task or question** highlighting a contradiction,
- Conclude with a question that reveals this contradiction,
- Frame the answer as an **unknown** to be resolved.

The assigned problems (tasks or questions) must:

- Be **comprehensible** to students,
- Account for their **cognitive abilities**,
- Be **essential** for acquiring new knowledge.

Methodology of Problem-Based Lectures

Like any lecture, a problem-based lecture involves a **logically structured oral presentation** that clearly and deeply explains the topic's core content. However, it incorporates key differences:

1. **Pre-prepared learning problems** (and sub-problems) are introduced during the lecture.

2. The instructor uses **methodological approaches**—posing problem-based questions, formulating hypotheses, validating or refuting them, analyzing scenarios—to encourage collaborative thinking and exploration of the unknown.

The Role of Dialogue

The **interactive nature of communication** is central to a problem-based lecture. The more dialogue-driven the lecture, the closer it aligns with true problem-based teaching. Conversely, a **monologue-style delivery** resembles traditional methods.

Two Critical Aspects of Problem-Based Lectures

1. A **system of questions or problems** reflecting the lecture's content.
2. A **dialogue-based discussion** between the lecturer and students regarding the knowledge being presented.

Analysis of Specific Situations as an Effective Method for Active Learning

Analyzing specific situations is one of the most effective and widely used methods for organizing active learning. This approach develops students' ability to analyze real-life and production-related problems. When encountering a specific situation, students must:

- **Identify the existence of a problem**,
- **Understand its essence**,
- **Determine their own stance toward the situation**.

Below, we present the organization of a **problem-based lecture** on the **fundamentals of equilibrium and non-equilibrium thermodynamics** in higher education institutions.

Core Problem Statement

We pose the following **central problem-based question**: *"Why are natural processes irreversible, and how can we explain the direction of these processes?"*

To address this, we construct a **system of problem-based questions** and engage students in active participation throughout the lecture to solve the core problem.

Key Problem-Based Questions

1. **First Law of Thermodynamics & Its Role in Nature**
   - *"What is the essence of the first law of thermodynamics, and what role does it play in nature?"*
   - After answering this, we raise the next issue:
   - *"Why can the first law not determine the direction of processes?"*
2. **Introducing Entropy & the Second Law**

- *"What quantity do we use to determine the direction of processes?"*
- This leads to the concept of **entropy**, its **statistical meaning**, and the **principle of entropy increase** in equilibrium systems.
- We emphasize that processes **only proceed toward thermodynamic equilibrium** (i.e., increasing entropy).

3. **Non-Equilibrium Thermodynamics & Self-Organization**

- In studying non-equilibrium thermodynamics, we highlight that the **second law of thermodynamics is a theory of "disruption."**
- We then pose the **main problem**:
- *"How can we explain nature's creativity—the emergence and evolution of ordered systems into higher, more complex forms?"*
- We note that **ordered states arise with a decrease in entropy**, which **contradicts the second law**.

4. **Resolving the Contradiction in Open Systems**

- While **entropy decrease** is observable in **open thermodynamic systems**, they must be considered as **parts of a larger closed system** where the second law still holds.

Supporting Problem-Based Questions for Discussion

1. To guide students in solving the main problem, we use the following structured questions:

How is the law of energy conservation defined in thermal processes?

2. What conditions are referred to as equilibrium and non-equilibrium states?
3. What are reversible and irreversible processes?
4. In what direction do natural processes occur?
5. What is the physical (statistical) meaning of thermodynamic probability and entropy concepts?
6. In what thermodynamic systems does entropy increase occur?
7. Under what conditions does entropy reach its maximum value?
8. Why doesn't heat spontaneously transfer from a cold body to a hot one?
9. Does "heat death" occur in the universe?
10. Why do we call equilibrium thermodynamics a "disruption" theory?
11. What does the concept of disorder or "chaos" mean?
12. Is the spontaneous emergence of ordered systems in nature contrary to the second law of thermodynamics?

13. Can entropy decrease be observed in open systems?
14. What systems are called "dissipative" systems?
15. Is the second law of thermodynamics valid in open systems?
16. Is self-organization phenomenon observed only in thermodynamic systems?

By systematically seeking answers to these auxiliary questions and discussing them, the solution to the main problem is found.

Conclusion

This article provides a brief analytical description of the problem-based lecture method belonging to active pedagogical technologies. The main focus was on the problem-based active learning method through lectures. The advantages of problem-based lectures based on comprehensive dialogue and interaction over traditional monologue-style lectures were demonstrated.

Problem-based lectures belong to active teaching methods. Student activity during lessons is of great importance. It is required to increase students' engagement in the learning process, directing their attention and cognitive activity towards solving the main problem. To achieve this goal, it was emphasized that creating a system of auxiliary problem-based questions in advance and using them purposefully is of great importance.

An example of organizing a problem-based lecture on the fundamentals of equilibrium and non-equilibrium thermodynamics was presented. Through active discussion of problem-based questions, creative approach to problems, and debates in rich learning environments, students grasp the essential nature of acquired knowledge rather than merely memorizing them as sets of information. As a result, they develop free and active thinking, creative aspiration, and practical problem-solving skills.

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