INTERNATIONAL MULTI DISCIPLINARY JOURNAL FOR RESEARCH & DEVELOPMENT
eISSN 2394-6334 Impact factor: 7,854 Volume 12, issue 12 (2025)

# MIND MAP–BASED VISUALIZATION OF PHYSICS CONCEPTS FOR DEVELOPING STUDENTS' IMAGINATION AND CREATIVE THINKING

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**Abstract:** Teaching most topics in natural sciences, particularly physics, requires reliance on students' imagination, as many physical processes cannot be perceived directly and can only be studied through their outcomes or with the aid of instruments and models. Human cognition addresses this limitation through thinking and analytical abilities, which are inseparable from imagination. Throughout history, imagination and creative thinking have enabled humanity to explore phenomena ranging from distant outer space to subatomic structures.

In order to prepare students to become qualified specialists in the future, it is essential to foster imagination and creative thinking skills already at the level of general education schools. This article argues that Mind Maps, as an effective tool for visualizing verbal information, provide favorable conditions for developing these cognitive abilities. The study presents methodological approaches to teaching the fundamental physics concept of energy and the law of conservation of energy through mind map–based visualization.

The findings demonstrate that mind maps support students' indirect understanding of physical processes by integrating visualization, imagination, and analytical reasoning. As a result, students develop deeper conceptual understanding, enhanced imagination, and improved creative thinking skills, which are essential for learning physics and addressing complex problems in modern education.

**Keywords:** physics education; mind map; imagination; creative thinking; visualization; indirect knowledge; idealization; modeling; energy; law of conservation of energy;

**Introduction**. The rapid renewal of scientific knowledge and the increasing integration of artificial intelligence into production processes have significantly intensified the demand for specialists equipped with creative thinking skills. Developing such competencies requires systematic efforts aimed at enhancing students' imagination, as imagination plays a central role in the formation of creative and flexible thinking. The development of imagination and creative thinking skills is primarily realized within the educational process and should begin at the level of general education schools.

Imagination enables learners not only to acquire new knowledge based on existing cognitive structures but also to transfer knowledge from one domain to another and apply it to solving novel and complex problems. Elements of imagination embedded in thinking, and cognitive processes enriched by imaginative representations, complement and reinforce one another. As noted by Albert Einstein, imagination is more important than knowledge, as knowledge is limited, whereas imagination embraces the entire world and stimulates intellectual progress.

In teaching natural sciences, particularly physics, it is often necessary to rely on students' imaginative capacities, as many physical phenomena cannot be directly perceived. Instead, they can be understood only indirectly—through experimental results, models, or technological instruments. Indirect knowledge is acquired by enhancing human sensory perception or facilitating observation, for example, through experimentation and modeling. At the same time, the interpretation and analysis of such knowledge require advanced thinking and reasoning abilities. These cognitive capacities allow humans to overcome physiological limitations and explore phenomena ranging from distant cosmic structures to microscopic nuclear processes.

To acquire indirect knowledge, learners employ a variety of cognitive methods, including idealization, which involves constructing simplified ideal objects to study real systems; modeling, which relies on analogy by substituting complex objects with more accessible representations; and experimentation, which transforms learners from passive observers into active investigators of natural phenomena. In physics education, these approaches are indispensable for conceptual understanding and meaningful learning.

Given these challenges, contemporary education must adopt instructional methods that effectively support imagination and creative thinking. One such method is the use of Mind Maps, which serve as a productive tool for visualizing verbal information and structuring complex concepts. By integrating visualization with analytical reasoning, mind maps create favorable conditions for developing students' imagination and creative thinking skills in physics education.

There are numerous pedagogical methods aimed at developing imagination and non-standard thinking skills. Among contemporary approaches, Mind Maps occupy a special place due to their cognitive and didactic potential in education. Mind maps enable the visualization of verbal information, thereby facilitating imagination and supporting deeper conceptual understanding.

Mind maps contribute to the systematic organization of information, clarify learning objectives, and encourage learners to compare concepts, identify associations, and establish analogies and metaphors during the process of perception. As a result, mind maps become an effective tool for analyzing information based on both standard and non-standard thinking processes. They also support the identification of cause–effect relationships and underlying algorithms within perceived information.

In educational practice, mind maps promote the development of spatial and visual intelligence, stimulate elements of fantasy, and encourage the emergence of non-standard ideas. At the same time, they provide opportunities for analyzing information through standard logical thinking, making them a productive means of fostering holistic thinking skills.

Research findings indicate that mind maps reflect the natural cognitive processes occurring in the human brain. In other words, individuals tend to think internally through mental maps that resemble the structure of mind maps. This correspondence between external visualization and internal cognitive organization explains the effectiveness of mind maps in learning and knowledge construction.

Mind maps are closely aligned with visual–imagery-based thinking, which is one of the earliest forms of thinking developed in children. They stimulate learners' interest in visualization and encourage reflection on processes occurring in the surrounding world. Structurally, mind maps resemble branching trees, where a central concept extends into major branches and further into smaller sub-branches, mirroring associative thinking patterns.

From a neurocognitive perspective, mind maps stimulate the coordinated activity of both hemispheres of the brain. They enable learners to visualize information at a glance, support radiant thinking characterized by the generation of multiple ideas, and foster creative exploration. By engaging both analytical and imaginative processes, mind maps enhance the efficiency of creative thinking activities and help learners anticipate potential outcomes and alternative scenarios.

Creative thinking allows individuals to foresee different possible future developments and construct multiple variants of events that may occur. In this sense, creative thinking represents a cognitive projection into possible future realities. Efforts to enhance the effectiveness of creative processes have historically led educators and philosophers to explore the structure and mechanisms of creative thinking. Even ancient Greek philosophers emphasized the importance of developing creative thinking abilities within the educational process.

**Research discussion.** One of the most effective ways to develop students' thinking and imagination is the use of problem-based questions. Such questions should not be limited to describing the properties or features of an object; rather, they should relate to the surrounding objective world and stimulate students' curiosity and cognitive interest. In physics education, carefully formulated questions encourage learners to think, imagine, and engage in creative reasoning.

Examples of problem-based questions used in physics instruction include the following:

When do we move faster around the Sun—during the day or at night?

Under what conditions could a bullet fire from a rifle be caught by hand?

How does gravitational force change as one approach the center of the Earth?

Why is smooth ice slippery, while smooth glass is not?

What would an electron "see" if it were riding on a nitrogen atom?

Such questions initiate the thinking process by creating a problematic situation, which serves as the starting point for cognitive activity. A problematic situation arises when learners recognize contradictions while attempting to solve a task or answer a question. The need to resolve these contradictions stimulates the search for new knowledge and promotes analytical and creative thinking.

Problem-based learning represents an instructional approach in which educational content is presented through the formulation and resolution of problems. To solve a given problem, students are compelled to explore, reason, and derive logical and scientific conclusions. This pedagogical approach was theoretically grounded by the American educator John Dewey, who emphasized the importance of inquiry and reflective thinking in education.

To illustrate the application of mind maps in physics education, this study examines methods for teaching one of the fundamental concepts of nature—energy—and the law of conservation and transformation of energy through mind map–based visualization.

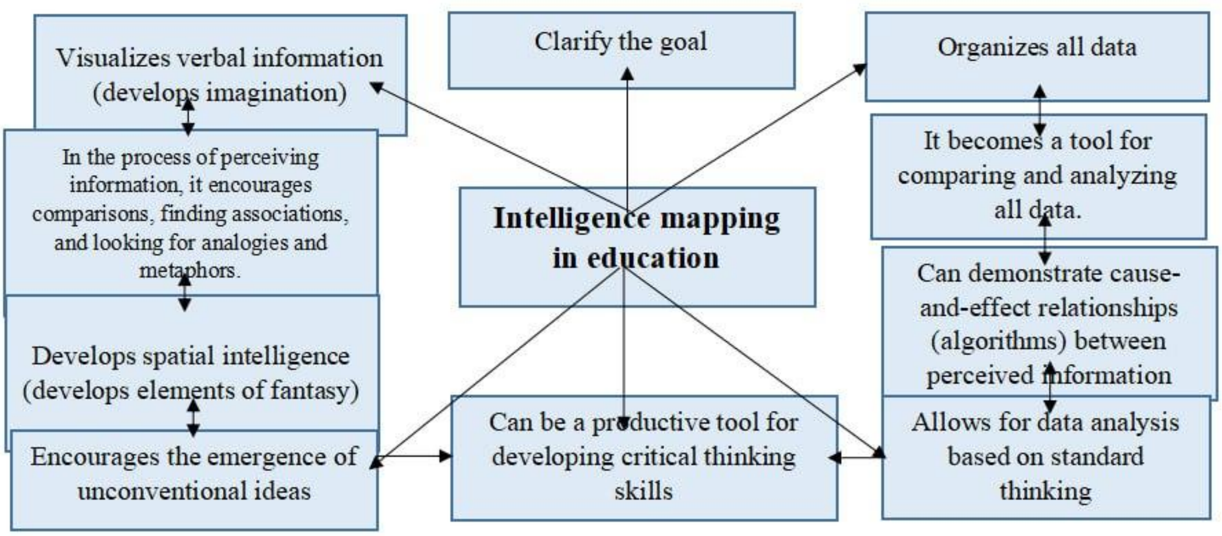


**Figure 1. Mind map illustrating the role of mind maps in education**

The law of conservation of energy states that energy is neither created nor destroyed in nature; it only transforms from one form into another. Numerous experimental studies and theoretical conclusions confirm the universal validity of this law. For this reason, it is often referred to as the law of conservation and transformation of energy. This principle applies not only to macroscopic systems but also to microscopic systems.

Energy transformations include conversions such as electrical energy into thermal, light, sound, or mechanical energy. Nuclear energy is associated with the configuration of nucleons within the atomic nucleus. During nuclear reactions, energy changes its form, transforming into the kinetic energy of particles and electromagnetic radiation, including light. However, the total mass–energy of the system remains conserved, as expressed by Einstein's equation $E = mc^2$, which demonstrates the intrinsic relationship between mass and energy.
Chemical energy, in contrast, is related to changes in the electron shells of atoms and corresponds to the sum of the energies of attraction between atoms and between electrons and protons. These transformations illustrate the diverse manifestations of energy in natural and technological processes.

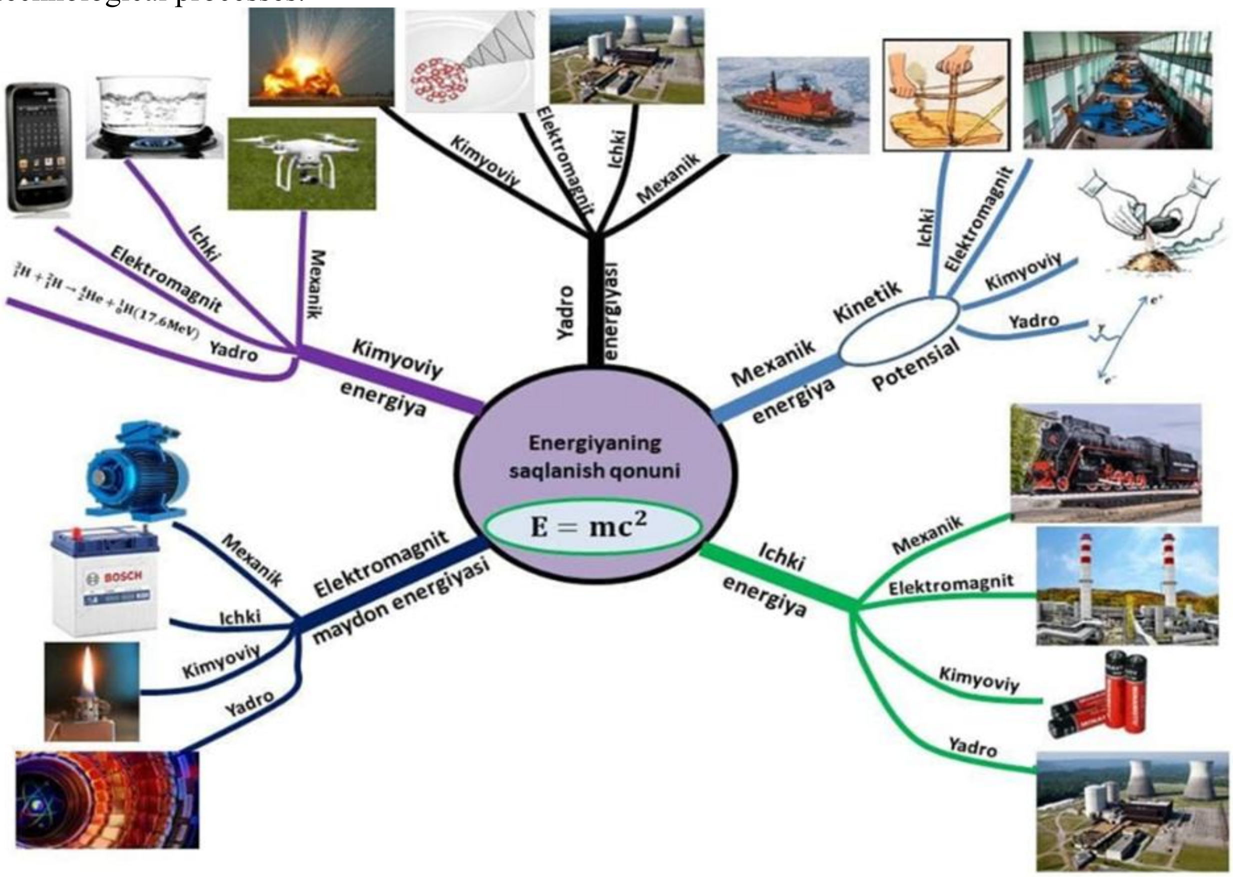


**Figure 2. "Law of Conservation and Transformation of Energy" mind map**

The mind map presented in Figure 2 visualizes the processes of energy transformation in nature. By organizing complex information into a coherent visual structure, it helps students imagine various physical processes and understand their occurrence in everyday life and technology. As a result, the use of this mind map supports the development of students' imagination and creative thinking skills, enabling deeper conceptual comprehension and integrative understanding.
The results of this study indicate that the use of Mind Maps in physics education creates favorable conditions for developing students' imagination and creative thinking skills, particularly in the context of learning abstract and indirectly observable phenomena. Physics concepts often require learners to rely on mental representations rather than direct perception, making imagination a crucial cognitive component of meaningful understanding.
The integration of problem-based questions with mind map–based visualization proved especially effective in stimulating students' cognitive activity. Problematic situations encourage learners to recognize contradictions, reflect on underlying physical principles, and search for

explanations beyond surface-level observations. This process activates both analytical reasoning and imaginative thinking, thereby supporting deeper conceptual engagement.

Mind maps also facilitate the development of holistic thinking, as they allow students to visualize relationships between concepts, processes, and laws within a single structured framework. In the case of the "Law of Conservation and Transformation of Energy," mind maps help learners perceive energy not as isolated definitions but as an interconnected system of transformations occurring in nature, technology, and everyday life. Such visualization strengthens students' ability to transfer knowledge across contexts and apply theoretical concepts to real-world situations.

Furthermore, the findings align with problem-based learning principles, which emphasize inquiry, exploration, and reflection as central elements of effective education. By organizing information visually and encouraging associative thinking, mind maps support both standard logical analysis and non-standard creative reasoning. This dual function is particularly valuable in physics education, where abstract reasoning must be complemented by imaginative visualization.

Overall, the discussion highlights that mind map–based visualization is not merely a supplementary instructional tool but a powerful pedagogical strategy for enhancing imagination, creative thinking, and conceptual understanding. When systematically integrated into physics teaching, mind maps contribute to the development of flexible, inquisitive, and creatively oriented learners who are better prepared to address complex scientific problems.

The rapid advancement of science and the increasing integration of artificial intelligence into production processes have intensified the demand for specialists equipped with creative thinking skills. Such competencies are formed and developed primarily through the educational process, making schools a critical environment for nurturing students' imagination and creative potential.

The findings of this study demonstrate that physics education offers substantial opportunities for developing students' imagination and creative thinking skills, particularly in the context of indirect knowledge acquisition. Since many physical phenomena cannot be directly perceived, students must rely on imagination, modeling, and analytical reasoning to construct meaningful understanding.

The use of Mind Maps as a tool for visualizing verbal information has been shown to produce positive educational outcomes. In particular, the "Law of Conservation and Transformation of Energy" mind map provides an effective framework for helping students visualize complex physical processes and understand their manifestations in natural and technological contexts. This visualization supports students' ability to imagine, analyze, and creatively interpret physical phenomena.

**Conclusion**. Overall, the systematic integration of mind map–based visualization into physics instruction contributes to the development of students' imagination, creative thinking, and holistic cognitive skills. By combining analytical reasoning with imaginative exploration, this approach enhances conceptual understanding and prepares learners to address complex scientific and technological challenges in contemporary education.

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