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THEORETICAL BASIS OF TEACHING ORGANIC CHEMISTRY IN SECONDARY SCHOOLS

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Abstract
This article analyzes the theoretical and methodological foundations of teaching organic chemistry in secondary schools. The research highlights the effectiveness of modern pedagogical technologies, particularly the "flipped classroom," multimedia tools, systemic tasks (SATL), and experiment-supported mechanistic approaches. It also psychologically grounds methods to reduce cognitive load, visualization challenges, and methodological difficulties in mastering organic compound nomenclature. The article discusses teachers' pedagogical content knowledge (PCK) and the potential of digital technologies.

Keywords: organic chemistry education, mechanistic reasoning, pedagogical content knowledge, flipped classroom, molecular models.

Introduction

Organic chemistry is one of the most complex and at the same time most interesting subjects in the general secondary education system. The three-dimensional structure of molecules, reaction mechanisms and complex nomenclature system require students not only memory, but also strong logical and spatial thinking. Nowadays, in the context of modernization of educational content, it is urgent to abandon traditional methods of teaching organic chemistry and switch to scientifically based modern approaches [11], [19].

For secondary school students, organic chemistry is often perceived as "abstract" and "incomprehensible". The main reason for this is the insufficient provision of the connection between macroscopic (observable phenomena) and submicroscopic (molecular level) concepts in the educational process [1], [14]. Researchers in chemistry education, for example, A. Johnstone, distinguish three levels in the study of chemistry: macroscopic, submicroscopic and symbolic (symbolic) levels. In organic chemistry, the integration of these three levels requires a high level of cognitive power from the student [11].

The purpose of this article is to reveal the theoretical and psychological foundations of teaching organic chemistry in secondary schools, analyze ways to solve existing methodological problems using modern technologies, and propose an effective model of teaching.

Research methodology

During the research, international and local scientific literature aimed at improving the effectiveness of teaching organic chemistry in secondary schools was analyzed. The following were identified as the methodological basis of the study:

- Systematic analysis: Systematic review of organic chemistry curricula and student learning indicators.
- Comparative analysis: Comparison of traditional and modern (flipped classroom, SATL, PBL) teaching methods.

• Pedagogical modeling: Development of a methodological model aimed at reducing cognitive load in teaching organic chemistry.

More than 25 scientific sources were studied, including monographs, textbooks, and articles in the Scopus and Web of Science databases [1]-[25].

Theoretical and psychological foundations of teaching.

Several fundamental theories are important in teaching organic chemistry.

Constructivism and social constructivism

The theory of constructivism (J. Piaget, L. Vygotsky) sees students as active creators of knowledge. In this approach, the teacher acts not as a transmitter of ready-made knowledge, but as a moderator guiding the process of student assimilation [3], [17]. Research by Iyamuremye et al. shows that web-based discussions activate students' knowledge construction (cognitive presence) in accordance with the principles of social constructivism [4].

Cognitive Load Theory and Visualization

Cognitive load theory, developed by A. Johnstone, is central to organic chemistry education. Many concepts in organic chemistry (e.g., isomerism, electronic effects, or reaction centers) can overload working memory. Research shows that teaching knowledge from the macro level (e.g., fuels, plastics) to the submicro level (atoms and bonds) reduces cognitive load [11]. Visualization tools, such as concept maps, help organize knowledge hierarchically [12].

Systemic Approach (SATL)

The Systemic Approach in Teaching and Learning (SATL) methodology involves teaching concepts as interconnected systems rather than as isolated facts. As noted by Ganajová et al. (2023), system diagrams help students see logical connections and think critically [6]. This method serves to overcome the difficulties of students in understanding the logical chain between nomenclature, reaction types and conditions (in about 60% of cases) [6].

Pedagogical Content Knowledge (PCK)

A teacher's effectiveness is determined not only by his knowledge of the subject, but also by his knowledge of how to convey it to the student (Pedagogical Content Knowledge). The theory of PCK requires combining content knowledge (Content Knowledge) with pedagogical strategies [15]. PCK in organic chemistry involves anticipating typical student errors (for example, errors in writing formulas) and using problem-based learning (PBL) [7], [18].

Analysis of modern pedagogical technologies

Today, information and communication technologies and interactive methods are widely used in organic chemistry lessons.

Multimedia and the Flipped Classroom

The 6Ps-based learning model (Nsabayezu et al., 2025) proposes a multimedia-enriched flipped classroom approach. In this, students learn theory through video materials before class and engage in active learning interactive activities during class [8]. This model increases students' motivation and conceptual understanding in mastering complex scientific concepts [8].

Molecular Modeling and 3D Visualization

Understanding the spatial structure of molecules is one of the most difficult aspects of organic chemistry. Physical molecular models (ball-and-stick) or digital modeling programs (PowerPoint, ChemDraw) allow students to better understand stereochemistry and nomenclature [9], [19]. According to Gyasi's research, working with a set of models significantly improved students' learning of IUPAC nomenclature [9].

Problem-Based Learning (PBL) and Inquiry

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Programs such as "Organic Chemistry in Action!" use an inquiry-based approach. This approach increases students' interest and knowledge by connecting chemistry to real-life contexts [20]. Problem-Based Learning (PBL) guides students to solve real-world problems, which in turn develops their cognitive skills [19].

Methodological problems and their solutions

The following main problems in teaching organic chemistry have been identified and solutions are proposed:

Nomenclature and symbolic language: Students have difficulty memorizing IUPAC nomenclature. Solution: Step-by-step teaching of nomenclature using digital tools and interactive worksheets [3].

Reaction mechanisms: It is difficult to visualize electron transfer and intermediate compounds. Solution: Experiment-based mechanistic explanation methodology (Building Bridges approach), i.e., directly linking laboratory experiments with mechanistic explanations [1].

Decontextualization: Failure to see the relevance of chemical theory to everyday life. Solution: Using the CTS (Science-Technology-Society) approach and teaching organic chemistry through the examples of food, medicine, and ecology [2], [10].

Teacher training: Many teachers have difficulty using new methods (e.g., SATL) (approximately 41%). Solution: Increase the number of webinars and methodological guides for teachers [6], [13].

Conclusions and recommendations

The theoretical foundations of teaching organic chemistry in secondary schools should be based on the principles of cognitive psychology, constructivism, and modern ICT. The following recommendations are proposed to improve teaching effectiveness:

- Organize lessons from macro to submicro to reduce cognitive load.
- Gradually introduce the "flipped classroom" and SATL models into the teaching process.
- Make the use of molecular modeling tools mandatory.
- Relate chemistry lessons to real-world problems (medicine, energy, ecology).

These approaches not only improve students' academic performance, but also develop a scientific worldview and critical thinking skills.

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