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IMPROVING THE METHODOLOGY OF TEACHING CHEMISTRY IN A COMPLEX MANNER BASED ON A MODERN PEDAGOGICAL APPROACH

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Abstract

This article analyzes the methodological foundations of improving the methodology of teaching chemistry in a comprehensive manner based on a modern pedagogical approach. The main goal of the paper is to develop students' thinking skills in analyzing and teaching chemical processes based on modern pedagogical approaches. During the research, the improvement of the methodology of teaching chemistry comprehensively based on modern pedagogical approaches and its impact on the level of student acquisition were studied. The results show that a systematic and algorithmic approach is the most effective tool in connecting theoretical knowledge with practice.

Keywords: chemical processes, teaching methodology, prospective chemistry teacher, instructional design, knowledge, qualification, skill, assessment.

Introduction

In today's context of globalization, preparing competitive pedagogical personnel who meet international standards and quality requirements of education is becoming more critical than ever. This is clearly reaffirmed by the noble ideal of “ensuring inclusive and equitable quality education and promoting lifelong learning opportunities for all,” put forward in the UNESCO 2030 Sustainable Development Agenda. This concept, in turn, requires teachers to work continuously on themselves and keep pace with the times.

Current trends in the international scientific and pedagogical arena are aimed at radically modernizing chemistry education alongside all other disciplines, introducing innovative approaches into the teaching process, and ultimately sharply increasing pedagogical efficiency. This is particularly crucial for chemistry, a subject rich in practical and laboratory sessions. The modern educational environment itself requires a new-generation teacher not only to thoroughly master theoretical knowledge, but also to possess the skills to effectively utilize dynamic visual materials, cutting-edge computer technologies, multimedia tools, and digital laboratory equipment in the classroom. Prospective teachers should no longer be confined to the traditional "chalk and blackboard" model, but must instead become specialists capable of navigating freely within a digital learning environment.

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The wide-scale reforms implemented in our Republic—specifically reforming the higher education system, elevating the quality of pedagogical personnel training to a new level, and meeting the practical demand and social need for the introduction of advanced technologies—further enhance the relevance of our study. The need to implement qualitative transformations in higher education and transition to a new stage of pedagogical cadre training has clearly mapped out the scientific and practical direction of our research.

Within the scope of the study, the scholarly works of our domestic researchers dedicated to chemistry teaching methodology, innovative pedagogical approaches, and the development of professional competence in prospective educators were thoroughly analyzed. Furthermore, we conducted a comparative review of the experiences of scholars from neighboring CIS countries as well as advanced practices from leading universities in abroad.

Literature review

In-depth scientific and methodological analyses revealed that although a number of notable research studies have been conducted in this area, systematic investigations devoted to comprehensively improving the methodological preparation of future chemistry teachers based on modern approaches—specifically digital technologies and innovative didactic tools—remain insufficient. This specific situation created a significant scientific gap, which fully justified the necessity of our dissertation research.

During the study, “Instructional Design” was extensively examined as a modern pedagogical approach. This concept is broader than a simple lesson plan; it is regarded as both a philosophy and a practical mechanism for organizing the entire learning process in a systematic, strategically targeted, and highly effective manner.

The main objectives of instructional design were defined as follows:

- delivering knowledge and practical skills to students in the most efficient manner;
- unifying complex educational processes into a coherent system and harmonizing all constituent parts;
- organizing educational activities in a clear, systematic, and result-oriented manner;
- developing flexible curricula tailored to each student's individual needs, proficiency level, and abilities;
- objectively evaluating the effectiveness of education based on the implemented design and continuously improving it.

As emphasized in the dissertation, acquiring instructional design skills serves prospective educators not only to successfully organize their pedagogical activities, but also establishes a solid foundation for cultivating creative thinking and lifelong professional self-improvement. In this context, the following key indicators reflecting the student's personal and professional development were identified:

- personal development (commitment to self-improvement);
- sustained interest in the profession;
- independent and critical thinking skills;
- high cognitive activity;
- harmony of scientific and practical outlook.

It has been established that the harmony of practical training and self-education-especially through laboratory sessions and active classroom participation-elevates the methodological readiness of the prospective teacher to a qualitatively new level.

Research methodology

The study examined the development of textbook competence in depth as a distinct and integral component of methodological training. The developed system of methods includes the following sequential stages:

a) Assimilating information at a convenient and individually tailored pace – teaching the student strategies for independent text-based work.
b) Deeply analyzing the textbook structure – identifying hierarchical connections among chapters, topics, sections, and basic concepts.
c) Working with figures, diagrams, and flowcharts – developing the ability to "read" and analyze visual data.
d) Retaining essential information – strengthening memory through mnemonic techniques and logical categorization.
e) Meticulous examination of the text – critical analysis of every paragraph, sentence, and chemical formula.
f) Drawing independent conclusions – synthesizing the learned material and formulating personal perspectives.

Consequently, it was scientifically justified that foundational competence elements are fostered in students, supporting both fundamental subject knowledge and continuous self-directed learning. As a practical outcome of the research, an integrated conceptual model was developed to cultivate the methodological training of prospective chemistry teachers. This model consists of five interconnected components:

- The *target component* identifies the strategic goal of upgrading methodological preparation to a qualitatively new level through innovative pedagogical technologies.
- The *theoretical-methodological component* harmonizes four core approaches-competency-based, systematic, integrative, and activity-oriented-as the scientific foundation of the research.
- The *content component* outlines the core curriculum around chemistry teaching methodology, modern pedagogical technologies, and interdisciplinary integration.
- The *organizational-pedagogical component* incorporates the most effective forms and techniques: problem-based lectures, interactive seminars, digital laboratories, extended pedagogical internships, design thinking, and case studies.
- The *outcome component* sets the final goal as the formed pedagogical competence and the ability to teach chemistry effectively using modern methods. To evaluate the degree of readiness objectively, a three-tier scale comprising high, medium, and low levels was adopted.

Problem-based learning was investigated as the most powerful instrument for instilling deep knowledge and solid skills in students. In this framework, students cease to be passive consumers of information and transform into truth-seeking researchers. They methodically dissect the situation at hand, compare similarities and differences, infer general laws from

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specific facts, and arrive at logical, substantiated, and scientific conclusions.

Such problem situations generate a continuous cognitive chain, ensure active collaborative learning, and stimulate intellectual development. Consequently, the learner evolves fully from a passive listener into an active investigating subject.

Taking into account the unique practical and theoretical nature of chemistry education, the study proposed a suite of interactive methods, whose effectiveness was verified through experimentation:

- Case study – analyzing real or simulated professional problems;
- Concept analysis – clarifying fundamental chemical concepts and establishing connections among them;
- Project-based method – developing independent or collaborative practical projects on specific topics;
- Venn diagram – comparing and synthesizing concepts, phenomena, or substances;
  -Brainstorming – seeking unconventional solutions to problems;
- Small group work – learning collaboratively and solving problems jointly.

Specifically, the primary aim of the case-study technique is to analyze, investigate, and draw evidence-based practical conclusions regarding real problem scenarios encountered in professional practice, thereby accelerating cognitive engagement, creative thinking, hands-on competencies, and autonomous decision-making skills.

To demonstrate practical efficacy, a problem-based questioning technique was designed and piloted for the traditionally challenging topic "Chemical Bonding."

At the beginning of the lesson, students are presented with a thought-provoking problem question:

“Why do NaCl (table salt) and HCl (hydrogen chloride) molecules exhibit drastically different physical and chemical properties, despite sodium and hydrogen sharing the same valence (I)?”

Through comparative analysis conducted collaboratively with the students, the following distinctions were identified:

- Table salt (NaCl): typical ionic compound; robust crystal lattice structure; exceptionally high melting point (801°C); aqueous solution and melt conduct electric current well.
- Hydrogen chloride (HCl): polar covalent compound; molecular structure; extremely low melting and boiling points (-114°C and -85°C, respectively); does not conduct electricity in its pure state.

Arising from this contradiction, the following foundational scientific deduction was formulated collaboratively:

“The properties of substances depend not only on the valence of elements, but primarily on the nature of the interatomic bond (ionic or covalent) and the lattice type (crystal or molecular).”

During instruction, “Chemical bonding” served as the core concept around which key concepts such as atom, electron, ion, covalent bond, ionic bond, and electronegativity were structured. This approach enabled students to comprehend the topic holistically and profoundly.

Analysis and results

Applying this interactive approach resulted in notable outcomes: in-depth comprehension of fundamental chemical concepts, improved team collaboration and collective decision-making, an atmosphere of academic dialogue, analytical and critical-logical thinking, and systematic consolidation of core chemical knowledge.

The fourth chapter of the dissertation outlines the comprehensive experimental work, detailing its organization and primary results. The experimental verification was structured into three consecutive phases:

1. *First phase:* introducing newly developed methodological recommendations and guidelines into the educational process.
2. *Second phase:* assessing students' theoretical and practical competence under the new methodology via midterm and final assessments.
3. *Final phase:* performing comparative mathematical-statistical analysis on the empirical findings gathered from both experimental and control groups to provide scientific substantiation.

- The final evaluation was carried out across four integral criteria:
  cognitive-informational criterion (scope and quality of theoretical knowledge);
- motivational criterion (intrinsic drive toward professional and academic endeavors);
- socio-psychological criterion (collaboration, communication, and reflective ability);
- operational-organizational criterion (practical and investigative skills).

Conclusion

The efficacy of the developed methodology was fully corroborated not only qualitatively, but also quantitatively through mathematical-statistical indicators. As an ultimate conclusion, the heightened efficacy of interactive and innovative methods over traditional approaches was proven. The chemistry educator of tomorrow must be modern, creative, technologically adept, problem-solving, self-improving, and capable of inspiring learners. The findings of this fundamental study conclusively substantiate the high efficacy of innovative approaches, interactive techniques, and contemporary pedagogical tools in advancing the methodological training of future chemistry teachers.

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