ТЕОРИЯ И МЕТОДИКА ОБУЧЕНИЯ И ВОСПИТАНИЯ (ПО ОБЛАСТЯМ И УРОВНЯМ ОБРАЗОВАНИЯ)/THEORY AND METHODS OF TEACHING AND UPBRINGING (BY AREAS AND LEVELS OF EDUCATION)

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ON ISSUES CONCERNING STUDENTS` RESEARCH COMPETENCIES FORMATION OF SECONDARY EDUCATIONAL INSTITUTIONS WHILE TEACHING CHEMISTRY

Research article

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Abstract
The given article dwells on the issues of formation of research competencies of students of secondary educational institutions in the process of teaching chemistry. It is noted that modern society needs creative and independent individuals with analytical abilities. In this regard, the formation and development of research competencies is one of the main tasks. In this regard, in the process of teaching chemistry in secondary educational institutions, the necessary conditions are created for the formation and development of analytical thinking and research competencies. The author believes that research competence should be taken into account at all levels of education, when teaching all subjects. The development of research competence in the process of teaching chemistry contributes not only to the improvement of knowledge of chemistry, but also to the development of an independent and creative personality.
Keywords: research competence, teaching method, experiment, analytical thinking, chemical experiments, teaching aids.

О ВОПРОСАХ ФОРМИРОВАНИЯ ИССЛЕДОВАТЕЛЬСКИХ КОМПЕТЕНЦИЙ СТУДЕНТОВ СРЕДНИХ ОБРАЗОВАТЕЛЬНЫХ УЧРЕЖДЕНИЙ В ПРОЦЕССЕ ПРЕПОДАВАНИЯ ХИМИИ

Научная статья

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Аннотация
В данной статье рассматриваются вопросы формирования исследовательских компетенций учащихся средних общеобразовательных учреждений в процессе обучения химии. Отмечается, что современное общество нуждается в творческих и самостоятельных личностях, обладающих аналитическими способностями. В связи с этим формирование и развитие исследовательских компетенций является одной из основных задач. В связи с этим в процессе обучения химии в средних общеобразовательных учреждениях создаются необходимые условия для формирования и развития аналитического мышления и исследовательских компетенций. Автор считает, что исследовательская компетентность должна учитываться на всех уровнях образования, при преподавании всех предметов. Развитие исследовательской компетентности в процессе обучения химии способствует не только совершенствованию знаний по химии, но и развитию самостоятельной и творческой личности.
Ключевые слова: исследовательская компетентность, метод обучения, эксперимент, аналитическое мышление, химические эксперименты, учебные пособия.

Introduction

The field of education is considered a key sector in the social policy of the Republic of Tajikistan and receives comprehensive support from the government. The contemporary educational landscape, particularly in the Republic of Tajikistan, emphasizes the cultivation of a generation capable of critical thinking and innovation. This priority is underscored by the declaration of 2020-2040 as the "Two Decades of Studying and Developing Natural Sciences, Exact Sciences, and Mathematics" by the nation's leadership [2], [10]. This strategic focus highlights the need to strengthen the teaching of subjects like chemistry, which are fundamental to scientific and technological progress.

Modern society requires individuals who are not merely repositories of information but creative and independent thinkers with well-honed analytical skills [9]. In this regard, the formation of research competence — defined as a set of knowledge, skills, and abilities that enable an individual to identify problems, gather and analyze information, and present evidence-based conclusions — has become a central task for educators [7], [12]. Research competence promotes intellectual curiosity, practical skills, and the ability to adapt knowledge to new situations.

Chemistry, as a discipline rooted in inquiry and experimentation, offers a unique and powerful platform for developing these competencies. The very nature of the subject — investigating the properties, structure, and transformations of matter — is inherently research-oriented. However, a systematic and methodical approach is required to fully harness this potential within the secondary school curriculum.

This article aims to explore the theoretical and practical aspects of forming research competencies in students through chemistry education, analyzing effective methods, organizational structures, and existing challenges.

Research methods

The corpus of our study is based on a systematic review and theoretical analysis of pedagogical literature and existing educational practices concerning research-based learning in chemistry. The methodological framework involves synthesizing strategies and approaches that have been identified as effective in fostering research skills.

The primary "methods" considered for implementation in the classroom, and thus analyzed in this paper, include:

1. The Research Method: This approach positions the teacher as a facilitator. Students are presented with a scientific problem or topic and guided through the process of investigation, mirroring authentic scientific inquiry [6], [11].

2. Project-Based Learning: Students develop and execute small scientific projects on relevant topics (e.g., "Recycling of Plastics," "Proteins — the Basis of Life"). This method encourages the integration of knowledge from various subjects and develops project management skills [4].

3. Laboratory Work with a Research Element: Moving beyond recipe-style experiments, this involves students designing aspects of an experiment, independently collecting data, and analyzing their results [5].

4. Integration of Information and Communication Technologies (ICT): The use of virtual laboratories and simulations allows students to conduct experiments that may be too dangerous, expensive, or impractical for a school setting, thereby expanding the scope of their research [1].

The planning of any research activity was conceptualized to include several key stages: problem identification, goal setting, experiment planning, working with scientific sources, conducting the experiment, analyzing results, and presenting findings.

Main results and discussion

The systematic integration of research-based pedagogy into secondary school chemistry education yields significant, observable outcomes in student development. The results of this methodological analysis are discussed thematically below, moving from the foundational cognitive processes to the practical implementation and measurable impacts.

3.1. Development of Hierarchical Cognitive and Metacognitive Skills

The formation of research competence is not a monolithic event but a hierarchical process that cultivates both cognitive and metacognitive abilities. Our analysis delineates three progressive stages of development:

Stage 1: Procedural Acquisition and Methodological Literacy. At this foundational stage, students acquire the fundamental language and tools of scientific inquiry. This includes mastering laboratory safety protocols, learning the correct usage of basic apparatus (e.g., burettes, pipettes, pH meters), understanding the principles of experimental design such as variable control, and developing the ability to follow structured methodologies for quantitative and qualitative analysis [3]. The outcome is methodological literacy — the ability to correctly execute a prescribed scientific procedure.

Stage 2: Applied Investigation and Hypothetical-Deductive Reasoning. Building on procedural competence, students advance to applying these skills in novel contexts. This stage is characterized by the engagement of hypothetical-deductive reasoning. Students are presented with a problem (e.g., "Determine the vitamin C content in different brands of orange juice") and must formulate a testable hypothesis, design an appropriate experimental procedure (e.g., using titration with iodine), and systematically collect data [5, P. 69]. The focus shifts from "how to do" to "what to do and why," fostering analytical thinking and problem-solving.

Stage 3: Critical Analysis, Synthesis, and Knowledge Construction. The most advanced stage involves the metacognitive processes of data interpretation, critical analysis, and knowledge synthesis. Students learn to process raw data, identify trends and anomalies, assess the validity and reliability of their results, and construct evidence-based conclusions [12, P. 100]. Presenting their findings through formal reports or presentations forces them to articulate their reasoning, defend their conclusions, and acknowledge limitations — a practice at the very heart of professional science.

3.2. The Pedagogical Efficacy of Inquiry-Based Methodologies

Our evaluation of specific pedagogical strategies reveals a clear hierarchy of efficacy in fostering research competencies.

Project-Based Learning (PBL) as a Simulated Research Cycle: PBL was identified as the most comprehensive method. A project such as "Investigating the Electrochemical Corrosion of Metals" requires students to engage in a full spectrum of research activities: literature review, experimental design (e.g., creating galvanic cells with different metal pairs), long-term observation, data logging, and final analysis. This mimics the authentic research cycle, fostering not only chemical knowledge but also project management and collaboration skills [4, P. 33–37].

Problem-Based Learning and Case Studies for Conceptual Challenge: Situational assignments and case studies (e.g., "Analyzing a local water sample for contaminant ions") force students to apply theoretical knowledge to ill-defined, real-world problems. This method is particularly effective in developing critical thinking, as students must discern which chemical principles are relevant and select appropriate analytical techniques from their repertoire.

Differentiated Laboratory Work: Moving beyond verification labs — which simply confirm known results — to inquiry-based labs is crucial. For example, instead of verifying the law of conservation of mass with a predetermined reaction, students could be tasked with designing and conducting their own experiment to test this law. This subtle shift transforms a routine activity into a genuine investigative challenge [7, P. 40].

3.3. Empirical Findings on Student Engagement and Conceptual Understanding

The implementation of these strategies correlates with two significant empirical outcomes:

1. Enhanced Conceptual Depth and Retention: The act of "discovering" a chemical principle through experimentation creates stronger neural pathways than passive reception of the same information. For instance, students who determine the rate of a reaction by measuring gas evolution under different temperatures internalize the principles of chemical kinetics more profoundly than those who merely memorize the Arrhenius equation. Research by Novikova [9] supports that student engaged in research activities demonstrate a superior ability to apply concepts in novel situations and exhibit higher long-term retention rates.

2. Increased Intrinsic Motivation and Scientific Self-Efficacy: The observed result of student-led inquiry is a marked increase in intrinsic motivation. The autonomy to direct aspects of their learning and the tangible satisfaction of solving a problem foster a sense of ownership and scientific self-efficacy. This is further amplified by integrating the history of science, specifically the contributions of scholars from the region like Al-Razi and Al-Biruni, which provides cultural relevance and role models, transforming chemistry from an abstract subject into a living, human endeavor [13, P. 143].

3.4. The Synergistic Role of Digital and Experimental Tools

The results clearly indicate that digital and physical tools are not mutually exclusive but synergistic. Virtual laboratories and simulations (e.g., PhET Interactive Simulations) provide a risk-free environment to explore complex or hazardous reactions, such as those involving volatile gases or extreme temperatures [1, P. 335]. This allows students to develop conceptual models and hypothesis-testing skills before or alongside wet-lab activities. The result is a more efficient and deeper learning process, where the virtual environment scaffolds understanding for the physical experiment.

3.5. Identified Challenges and a Framework for Mitigation

Despite the demonstrated benefits, the analysis confirms significant impediments. The most critical challenge is the discrepancy between the theoretical embrace of inquiry-based learning and the practical constraints of the classroom environment.

Resource and Time Constraints: The scarcity of modern laboratory equipment and the pressure of a crowded curriculum often force teachers to default to traditional, lecture-based methods.

Assessment Misalignment: Standardized assessments often prioritize factual recall over research skills, creating a disincentive for teachers to invest time in lengthy projects.

To address these, a systemic framework is required:

Curriculum Modernization: Integrating research skill development as a explicit, assessable learning outcome within the national chemistry curriculum [8].

Teacher Professional Development: Ongoing training for educators is essential, focusing not just on the "what" of research methods but the "how" of managing open-ended inquiry in a resource-constrained setting.

Development of Low-Cost, High-Impact Experiments: Promoting the use of microchemistry kits and locally sourced materials can democratize access to hands-on experimentation.

In synthesis, the discussion affirms that a scientifically grounded approach to forming research competencies — one that is staged, methodologically diverse, and supported by appropriate tools — produces a transformative effect on chemistry education. It shifts the paradigm from knowledge transmission to knowledge construction, ultimately cultivating the analytical, independent, and innovative individuals essential for scientific and societal progress.

Conclusion

Thus, the corpus of our study addresses the crucial issue of cultivating research competencies among secondary school students through chemistry education. In an era marked by rapid technological advancements and increasing demands for innovation, fostering analytical thinking and independent inquiry skills is paramount. It's critical that chemistry education moves beyond rote memorization of facts and toward providing students with the tools and opportunities to engage in genuine scientific exploration. As the emphasis on STEM education intensifies, teachers must adopt strategies that stimulate intellectual curiosity and foster a deeper understanding of chemical principles.

The analysis presented here has demonstrated that secondary school programmes can provide foundational chemistry knowledge. However, to promote research skills development, improvements to teaching practices are required. The focus on governmental development and the strategic focus of key programmes emphasizes the importance of chemistry and related STEM areas. This must be matched with training of instructors, modernization of learning environments, and the prioritisation of methods that encourage self-directed learning. The integration of project-based learning, interdisciplinary approaches, and technology-enhanced simulations are seen as promising avenues for enhancing research competencies. By nurturing these skills, educators not only improve students' understanding of chemistry but also prepare them for success in higher education, future careers, and active participation in a knowledge-driven society.

Future research should focus on developing and evaluating specific pedagogical interventions designed to enhance research competence in the secondary school chemistry curriculum. This includes exploring the effectiveness of various teaching methods, assessing the impact of technology integration, and developing valid and reliable instruments for measuring student research skills. Furthermore, investigations into teachers' professional development needs and resources should be supported. By continuing to explore and refine these approaches, we can ensure that future generations are equipped to tackle the complex scientific and technological challenges facing our world.

Конфликт интересов

Не указан.

Рецензия

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Conflict of Interest

None declared.

Review

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