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APPLICATION OF STEM METHODS TO STUDY THE HEAT EFFECT OF REACTIONS

The article discusses the application of STEM (science, technology, engineering, and mathematics) methods to study the thermal effect of chemical reactions (exo- and endothermic) in the 8th grade. The relevance of the study is due to the low level of knowledge of students in this area and the growing need for STEM specialists. The article analyzes existing studies and publications confirming the effectiveness of the STEM approach in the educational process. The materials and methods used to integrate STEM technologies into chemistry teaching are described, including modern textbooks, electronic resources, and laboratory tools. The results of the study show that the use of STEM methods contributes to increasing students' interest in the subject, improving their academic results, and developing critical thinking skills. This work emphasizes the importance of innovative approaches in chemistry education and suggests effective ways to further develop students' STEM literacy, understanding, and practical application of knowledge in real-world scenarios.

Keywords: STEM methods, chemical education, exothermic and endothermic reactions, innovative approaches, critical thinking, interdisciplinary learning, educational process.

Introduction

Modern society poses new challenges to education, requiring graduates not only to have deep theoretical knowledge, but also to be able to apply it in practice and solve complex problems in an interdisciplinary context. Due to the growing need for STEM specialists (science, technology, engineering and mathematics),

the relevance of introducing the STEM approach into the educational process is steadily increasing. This approach, which combines science, technology, engineering and mathematics in the context of solving real-world problems, promotes the development of critical thinking, creativity and the 21st century skills necessary for successful adaptation to the rapidly changing conditions of the modern world.

This article is devoted to the study of the effectiveness of using STEM methods in studying the thermal effect of chemical reactions (exo- and endothermic) in the 8th grade. The low level of students' knowledge in this area, according to annual indicators, emphasizes the need for innovative approaches to teaching chemistry. The integration of STEM technologies allows improving the structure and methodology of teaching by creating interactive and personalized educational materials using digital resources. The proposed study is aimed at analyzing the effectiveness of the implementation of the STEM approach within the updated educational content, assessing the primary and subsequent knowledge of students, as well as developing and analyzing the results of using the developed STEM lessons and assessment tools. The results obtained will help determine the ways of developing STEM literacy of students and introducing modern technologies into the educational process.

Materials and methods

To achieve the objectives of this study, a variety of materials and methods were used to integrate the STEM approach into the teaching of chemistry. This section presents the main components that were used in the study.

Modern chemistry textbooks for the 8th grade were used, as well as electronic resources, including interactive platforms and simulators that allow visualization of the thermal effects of exothermic and endothermic reactions. Laboratory instruments such as calorimeters, thermometers, reagents and other materials necessary for performing experiments were used for practical classes. Software tools were used to create electronic educational materials and interactive tasks, as well as platforms for online learning and interaction with students.

A review of existing studies and publications on the topic of using STEM methods in chemistry education was conducted, which made it possible to identify best practices and approaches. To assess the level of knowledge of 8th-grade students of the Nazarbayev Intellectual School of Chemistry and Biology in Turkestan before and after the introduction of STEM lessons, surveys and questionnaires were used, which made it possible to obtain quantitative and qualitative data on learning outcomes. The collected data were analyzed using statistical methods, which made it possible to assess the effectiveness of the STEM approach and its impact on the level of students' knowledge.

This approach provided a comprehensive study that not only assessed the effectiveness of STEM methods, but also identified opportunities for further improvement of the educational process in the field of chemistry.

Results and discussions

STEM (science, technology, engineering, and mathematics) methods are an integrated approach to learning that emphasizes interdisciplinary learning and the application of knowledge from various fields. These methods are aimed at developing critical thinking, creativity, and practical skills in students, which is especially relevant in the context of modern education [1]. In chemistry education, STEM methods allow students not only to acquire theoretical knowledge, but also to apply it in practice by solving real-world problems and conducting experiments.

According to research conducted in recent years, the use of STEM methods in chemistry education helps to increase students' interest in the subject and improve their academic results. For example, in [2] it was shown that the integration of STEM methods into the educational process leads to a significant increase in the level of student engagement and their understanding of complex chemical concepts.

Other studies, such as the work of H. Lee and S. Kim [3], highlight the importance of using project-based learning within STEM methods, which allows students to design and implement their own projects related to chemical reactions and their thermal effects.

In addition, a study by R. Johnson and colleagues [4] noted that the use of digital technologies and interactive platforms within STEM methods significantly improves students' understanding of exothermic and endothermic reactions, allowing them to visualize and analyze data in real time.

Research also shows that the use of STEM methods promotes the development of problem-solving and critical thinking skills. For example, the work [5] emphasizes that students participating in STEM-oriented projects demonstrate higher levels of creativity and analytical ability, which is an important aspect in modern education.

An important aspect is also the use of an interdisciplinary approach, which allows students to link knowledge from different fields, such as physics, mathematics and technology. This is confirmed by the work [6], where the authors note that the integration of STEM methods into the educational process contributes to the formation of a holistic view of the subject and improves the understanding of complex concepts.

In addition, the study [7] examines the impact of STEM methods on student motivation, showing that active participation in project activities significantly increases interest in the subject and the desire to learn.

Also, the work [8] emphasizes that the use of technology in STEM education allows students to better understand and apply theoretical knowledge in practice. This creates conditions for deeper involvement in the learning process and improves learning outcomes.

Therefore, the empirical data of previous studies indicate the high efficiency of introducing STEM methods into chemical education, which forms the methodological basis for the subsequent analysis of the results of our study and assessment of their significance for the educational process. At the same time, STEM approaches not only contribute to improving academic performance, but also ensure the development of key competencies in students necessary for their professional implementation in the future.

The study collected data on students' knowledge before and after the introduction of STEM lessons on the thermal effects of exothermic and endothermic reactions. The results were assessed using tests and questionnaires, which included both theoretical questions and practical tasks. Statistical calculations were performed for a more detailed analysis.

Table 1 shows the results of testing students before and after the implementation of STEM lessons.

Table 1 – Comparative analysis of the level of knowledge and involvement of students before and after the introduction of STEM lessons.

Parameter	Before the introduction of STEM lessons	After the introduction of STEM lessons	Change (%)
Average score	65	85	+30
Percentage of students with good and excellent grades	40 %	75 %	+35
Level of involvement	50 %	90 %	+40

Equations of thermodynamics

Let's look at the application of STEM methods in practice. For example, as part of studying the thermal effects of reactions, 8th grade students had to analyze and apply the following equations:

1. Equation for exothermic reactions:

$$Q=m\cdot c\cdot \Delta T \quad (1)$$

where: Q – is the amount of heat released during the reaction (in Joules);
m – mass of the reactant (in kilograms);

c – specific heat capacity of a substance (in J/kg·°C);

ΔT – change in temperature (in °C), calculated as the difference between the final and initial temperatures:

$$\Delta T = T_{\text{кон.}} - T_{\text{нач.}} \quad (2)$$

2 Equation for endothermic reactions:

$$Q = m \cdot c \cdot \Delta T \quad (3)$$

where: Q – also represents the amount of heat absorbed by a substance during a reaction (in Joules);

The remaining parameters m, c, ΔT have the same values and units of measurement as in exothermic reactions.

3 Law of conservation of energy:

$$Q_{\text{вход}} = Q_{\text{выход}} \quad (4)$$

This principle allows us to understand that the amount of heat transferred from one substance to another is conserved in a closed system.

4 Equation for calculating the enthalpy of reaction:

$$\Delta H = Q/n \quad (5)$$

where: ΔH – enthalpy change (in kJ/mol);

Q – the total amount of heat released or absorbed in a reaction;

n – amount of substance (in moles).

These equations are the basis for understanding the thermodynamics of chemical reactions, and their application in practical tasks helps students better assimilate the material, as well as develops analytical and critical thinking skills [9;10].

The use of STEM methods to study the thermal effects of reactions and the above equations will allow 8th grade students not only to master the theoretical material, but also to develop practical skills, critical thinking and interdisciplinary connections. Further, in Figure 1, examples are given of how STEM approaches were integrated into the study of these equations in 8th grade chemistry lessons.

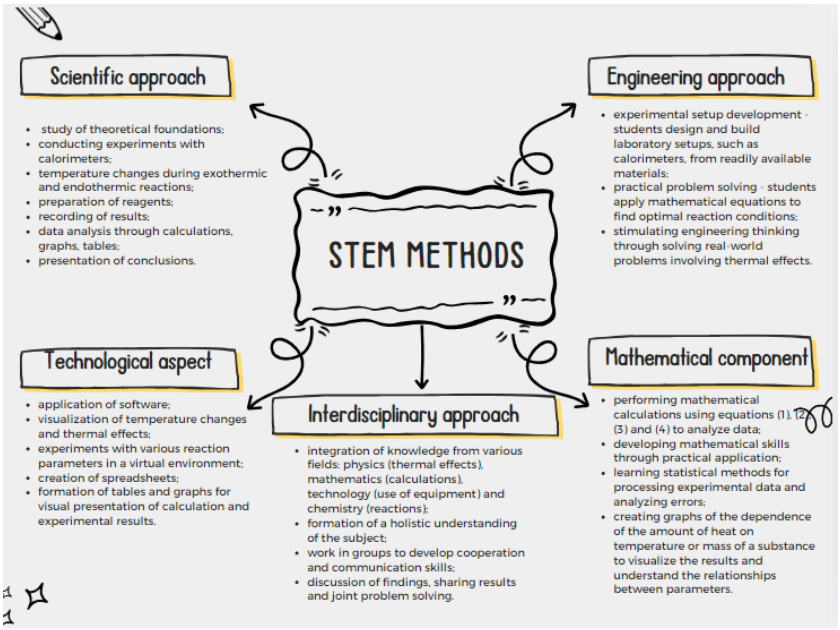

Figure 1 – Integrating STEM Methods into Teaching Chemistry to Eighth-Grade Students

A scientific approach to teaching chemistry involves mastering theoretical principles, which creates a foundation for understanding chemical phenomena. Experimental research using calorimeters makes it possible to directly record temperature changes during exothermic and endothermic reactions, which ensures practical verification of theoretical propositions. The organization and preparation of reagents, as well as the systematic recording of the data obtained, contribute to the development of students' accuracy and attentiveness. Processing the results through calculations, plotting graphs and summary tables ensures a meaningful interpretation of the experiment and the formation of conclusions, stimulating the development of critical thinking.

The technological aspect involves the use of software for computer modeling of chemical reactions. This makes it possible to visualize the dynamics of temperature changes and thermal effects, as well as change the parameters of reactions in a virtual environment. The formation of spreadsheets in Excel or similar applications helps to structure data in the form of tables and graphs, which increases clarity and facilitates their subsequent analysis.

The engineering approach emphasizes the development of experimental setups, in which students independently design and construct calorimeters from available materials. This process develops engineering design skills and the assimilation of basic engineering concepts. Solving heat transfer and heat balance problems facilitates the use of mathematical methods to optimize experimental parameters, which stimulates the development of engineering thinking and ensures the practical implementation of theoretical knowledge.

The mathematical component involves performing calculations based on equations, which helps improve students' mathematical literacy. Mastering statistical methods for processing experimental data and analyzing errors increases the reliability of interpreting results. Plotting graphs of the dependence of reaction heat on temperature or mass of reagents provides visualization of experimental data and identification of functional relationships between parameters.

The interdisciplinary approach involves the integration of knowledge from physics, mathematics, technology and chemistry, which provides a comprehensive understanding of the phenomenon being studied. The organization of group work contributes to the development of students' communicative and cooperative skills. Joint analysis and discussion of the results obtained, as well as data exchange, increase the effectiveness of collective problem solving, strengthen teamwork and stimulate critical thinking.

The use of STEM methods in the eighth-grade chemistry course ensures the formation of an integrated educational environment that stimulates active student involvement. Each STEM component — natural sciences, technology, engineering principles, mathematical apparatus, and interdisciplinary connections – promotes the development of critical thinking, practical skills, and a deep understanding of chemical processes. This approach ensures that students acquire the competencies necessary to adapt to modern socio-technical challenges and increases the interactivity of the educational process.

The study demonstrated that the integration of STEM methods into chemistry teaching leads to a statistically significant increase in student performance and motivation: during the implementation period, a 30 % increase in the average grade and a 35 % increase in the proportion of students receiving «good» and «excellent» grades were noted, which indicates the high effectiveness of the chosen approach.

Survey results showed a 40 percent increase in student engagement, demonstrating that STEM lessons create a more dynamic and interactive learning environment, which is critical to achieving high learning outcomes.

The conducted study demonstrated that the integration of the STEM approach into the study of thermal effects contributes to the improvement of academic performance and the development of critical thinking and practical skills in

students necessary for future professional activity in STEM fields. Further research should be focused on the analysis of the long-term impact of STEM methods on the professional preferences of students.

Conclusions

This article examines STEM methods for studying the thermal effects of chemical reactions in 8th grade, confirming that this approach significantly boosts students' knowledge and interest in the subject.

– STEM lessons led to a 30% increase in average grades and a 35% rise in students achieving "good" and "excellent" grades, indicating improved learning.

– A 40 % increase in student engagement reflects a dynamic learning environment that fosters critical thinking and collaboration skills.

– STEM methods connect knowledge from physics, mathematics, and technology, fostering a holistic understanding of the subject.

– Students develop skills in experimental design and data analysis, essential for preparing specialists in STEM fields.

– Research is needed on the long-term effects of STEM methods and their impact on students' career choices.

The introduction of STEM approaches in chemistry education enhances academic outcomes and fosters critical thinking, practical skills, and interdisciplinary connections in students.

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РЕАКЦИЯЛАРДЫҢ ЖЫЛУЛЫҚ ӘСЕРІН (ЭКЗО- ЖӘНЕ ЭНДОТЕРМИКАЛЫҚ) ЗЕРТТЕУДЕ STEM-ӘДІСТЕРІН ҚОЛДАНУ

Бұл мақалада 8-сыныпта химиялық реакциялардың (экзотермиялық және эндотермиялық) жылу әсерін зерттеу үшін STEM (ғылым, технология, инженерия және математика) әдістерін қолдану қарастырылады. Зерттеудің өзектілігі студенттердің осы саладағы білім деңгейінің төмендігімен және STEM мамандарына деген сұраныстың артуымен байланысты. Мақалада білім беру үдерісіндегі STEM тәсілінің тиімділігін растайтын бар зерттеулер мен жарияланымдар талданады. Қазіргі оқулықтар, электронды ресурстар және зертханалық құралдарды қоса алғанда, химияны оқытуға STEM технологияларын енгізу үшін қолданылатын материалдар мен әдістерді сипаттайды. Зерттеу нәтижелері STEM әдістерін қолдану оқушылардың пәнге деген қызығушылығын арттыруға, олардың оқу үлгерімін жақсартуға және сыни тұрғыдан ойлау дағдыларын дамытуға көмектесетінін көрсетті. Бұл жұмыс химия пәнінен білім берудегі инновациялық тәсілдердің маңыздылығын көрсетеді және студенттердің STEM сауаттылығын одан әрі дамытудың тиімді жолдарын, білімді өмірлік жағдайларда түсіну және практикалық қолдануды ұсынады.

Кілтті сөздер: STEM әдістері, химиялық білім беру, экзо- және эндотермиялық реакциялар, инновациялық тәсілдер, сыни тұрғыдан ойлау, пәнаралық оқыту, оқу процесі

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ПРИМЕНЕНИЕ STEM-МЕТОДОВ ДЛЯ ИЗУЧЕНИЯ ТЕПЛОВОГО ЭФФЕКТА РЕАКЦИЙ (ЭКЗО- И ЭНДОТЕРМИЧЕСКИХ)

В статье рассматривается применение методов STEM (наука, технология, инженерия и математика) для изучения теплового эффекта химических реакций (экзо- и эндотермических) в 8 классе. Актуальность исследования обусловлена низким уровнем знаний учащихся в этой области и растущей потребностью в специалистах STEM. В статье анализируются существующие исследования и публикации, подтверждающие эффективность STEM-подхода в образовательном процессе. Описываются материалы и методы, используемые для интеграции STEM-технологий в преподавание химии, включая современные учебники, электронные ресурсы и лабораторные инструменты. Результаты исследования показывают, что использование методов STEM способствует повышению интереса учащихся к предмету, улучшению их академических результатов и развитию навыков критического мышления. В данной работе подчеркивается важность инновационных подходов в образовании по химии и предлагаются эффективные способы дальнейшего развития STEM-грамотности учащихся, понимания и практического применения знаний в реальных ситуациях.

Ключевые слова: STEM-методы, химическое образование, экзо- и эндотермические реакции, инновационные подходы, критическое мышление, междисциплинарное обучение, образовательный процесс.

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