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STUDYING CHEMISTRY AT SCHOOL: OVERCOMING CHALLENGES TOGETHER

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Abstract. The most important theoretical and methodological aspects of studying chemistry in general secondary education institutions have been analyzed. To gain a deeper understanding of the challenges faced by secondary education students during the study of chemistry, a diagnostic experiment was conducted. An anonymous survey was conducted among students of grades 7–9 at Lviv Secondary School No. 67 (Ukraine). The results of the diagnostic experiment revealed that the main difficulties faced by students include low interest in the subject, challenges in understanding certain concepts, laws, and theories, as well as insufficient connection to practical applications in real life. A survey showed that 65% of 9th-grade students, 55% of 8th-grade students, and 35% of 7th-grade students consider chemistry to be a more difficult subject than physics or biology. Chemistry is most often associated with interest – 55.2% and fear – 26.5%, while some students feel boredom during lessons – 9.6%. Other emotions mentioned by students included surprise, sadness, and others. Approximately 60% of students believe that chemistry is closely related to other subjects, including physics, mathematics, and biology, while approximately 40% said that there is no such relationship. 15% of students believe that chemical knowledge can be practically applied in daily life, over 60% see only partial usefulness, and 25% consider it insignificant and fail to see any practical benefit. Approximately 75% of students expressed a desire to increase the practical (experimental) component of lessons. Students' self-assessment of their level of skills and knowledge in chemistry indicated that 13% of 7th-grade students, 23% of 8th-grade students, and 5% of 9th-grade students demonstrate a low level of proficiency. A sufficient level was observed in 45%, 54%, and 5%, while an average level was reported by 35%, 20%, and 85% of the students respectively. The article provides practical recommendations for solving difficulties that often arise when studying chemistry and improving the quality of the educational process.

Keywords*:* educational process, institution of general secondary education, students of secondary education, studying chemistry, interactive technologies.

1. INTRODUCTION

Chemistry is a unique discipline that holds a special place among the natural sciences. It is a fundamental science of nature, and its study in secondary education institutions has not only a worldview significance for a scientific perception of the world but also plays a crucial role in shaping a student's personality, developing their creative abilities, critical thinking, and the ability to apply acquired knowledge in practice. Chemical education lays the foundation for forming individuals with a "scientific worldview" capable of "civilized interaction with nature" (State Standard of Basic Secondary Education, 2020). Chemical literacy is an integral component of a person's overall culture.

Effective teaching of chemistry in general secondary education institutions is essential for

developing students' scientific literacy and critical thinking skills. Teacher plays a key role in guiding students' cognitive activities, adjusting new information, and facilitating joint discussion and analysis. The teacher must be a skilled professional, proficient in various teaching methods, capable of formulating chemistry-related tasks, demonstrating the possibilities of chemical experiments, implementing interdisciplinary connections, and fostering students' ability to apply acquired knowledge in everyday life (Espinosa, et al., 2025).

Today, the phased implementation of the State Standard of Basic Secondary Education continues, aimed at changing the organization of the educational process to provide opportunities for students to develop key and subject competencies and cross-cutting skills defined by the Law of Ukraine "On Education" by the Concept of New Ukrainian School.

However, studying and learning chemistry can be challenging, and certain issues sometimes arise in school practice that hinder successful mastery of the subject. These include low motivation, stereotypes about the complexity of chemistry, and a lack of understanding of its clear connection to real life. The relevance of the work is not only to recognize how and why students have certain difficulties in learning chemistry but also to be able to predict, avoid, and overcome them.

2. THEORETICAL FRAMEWORK

The analysis of research and publications indicates that many scholars have dedicated their work to education and learning, including the study of chemistry in general secondary education institutions.

The famous American philosopher and educator John Dewey viewed education as "a common endeavor in which both students and teachers improve their understanding through constant dialogue and cooperation". In his view, education must be fundamentally democratic. Its primary goal is not only to impart knowledge but also to shape students' moral and social positions. The educator emphasized the dialogical nature of communication and its role in the development of critical thinking (Dewey, 2003, 294 p.).

The Czech educator John Amos Comenius, in his work "The Great Didactic", not only developed a clear system of teaching and upbringing but also revealed the essence of its fundamental principles: visuality, awareness and activity, consistency and systematic knowledge, and thorough mastery of knowledge and skills. He emphasized a systematic approach to the educational process and advocated for close collaboration between teachers and students to achieve educational goals. He emphasized the importance of regular information exchange and constant interaction through questions, answers, and explanations (Levkivskyi & Pashchenko, 2016, pp. 42-48). The educator believed that the future of a state and its people depends on how the education, teaching, and upbringing of the younger generation are organized.

The prominent Ukrainian scholar and founder of scientific pedagogy, Kostyantyn Ushynsky, emphasized the need to consider students' psychological characteristics in the learning process. He argued that "effective interaction depends not only on the teacher's efforts but also on the active participation of students, their motivation to learn and mutual understanding with the teacher". According to Kostyantyn Ushynsky, the central figure in the educational process is the teacher, who must be adequately prepared for their teaching role (Kazakova & Pasitska, 2014, pp. 164-171). Kostyantyn Ushynsky considered the correspondence between the difficulty of the educational task and the ability of students to overcome it to be an inviolable law of learning so that the student has exactly as much to do as his young strength can overcome (Vasyanovych, 2014, pp. 22-32).

The development of methodological foundations for forming students' chemical concepts and knowledge is the subject of the works of Lyudmyla Velychko (2013, pp. 7-13), Iryna Gurnyak (2009, pp. 39-50), Lyudmyla Lypova (Lypova et al., 2006, pp. 35-41), Nadiya Chajchenko (2001, 163 p.), Alla Shevchenko (2015, 20 p.), and Olga Yaroshenko (2024, pp. 28-32).

In this context, it is worth mentioning the works of Polish humanists who emphasize interactivity in

education. Olena Budnyk (2024) describes the theory of duality of the contemporary Polish scholar Lech Witkowski, which presents a dynamically changing contradiction, which consists, on the one hand, in the need to be open to dialogue, active communication, interactive perception of the 'Other', and, on the other hand, in the ability to overcome this level of perception. To do this, it is necessary to respect the opinion of the interlocutor (e.g. a student), take into account his/her experience in parity interaction, and at the same time show communicative readiness to pull the recipient out of a certain anomaly' if necessary, overcome the difficulties of 'going beyond the level of the addressee' and ultimately achieve a qualitatively higher level of interaction and value development (Witkowski 2017, p. 382). In the process of learning chemistry, we build active interactive interaction for a deeper understanding and improved quality of education.

Efforts to improve the organizational forms, methods, and tools of chemistry teaching in general secondary education institutions have been undertaken by Olga Berezan (2002), Oleh Blazhko (2008), Volodymyr Starosta (2003, pp. 158-163), Pavlo Khomenko (2007, pp. 225-227), Kristen K. B (2017, pp. 223), E. Indrawan (2019), and others. Information and communication technologies were used in chemical education (Kumar & Chauhan, 2014, pp. 281-299; Rodrigues, et al., 2018, pp.172-191; Ahmad & Arshad, 2018, pp. 67-74), including virtual laboratories for conducting experiments in education. (Dziabenko, & Budnyk, 2019). Numerous chemists and educators have worked on the methodology and techniques of school chemical experiments, including Oleksandr Astakhov (1984, p. 128), Nina Burynska (2007, p. 112), Andriy Grabovyi (2008, pp. 53-57), Mariya Savchyn (2003, pp. 36-44; Savchyn, 2016, pp. 5-2), Nadiya Chajchenko (2001), Hanna Lashevska (2009, pp. 13-14), and others.

The purpose of the study is to analyze the theoretical and methodological aspects of chemistry in secondary education institutions, identify the challenges faced by secondary education students in the process of learning chemistry, and outline strategies for overcoming these challenges. For this purpose, the following *research objectives* were defined:

1. Based on an analysis of scientific and methodological literature, examine the current state of the problem and evaluate the most significant theoretical and methodological aspects of teaching chemistry in general secondary education institutions.
2. Conduct a diagnostic pedagogical experiment to identify the difficulties encountered by secondary education students in the process of learning chemistry and determine the causes and means of overcoming these difficulties.

3. RESULTS AND DISCUSSION

During the diagnostic phase of the experiment aimed at identifying the difficulties faced by secondary school students in studying chemistry, we conducted a survey involving 178 students from grades 7–9 at Lviv Secondary School No. 67 (Ukraine). The questionnaire consisted of 18 questions. It was important for us to find out the studentsє attitudes towards chemistry, the difficulties they encounter in studying the subject and what they are related to, their preferences regarding teaching methods, and suggestions for improving chemistry lessons.

To the question, "*Do you like studying chemistry?*" 29.6% of students responded 'yes', stating that it is their favorite subject; 11.6% answered 'no', considering it their least favorite and uninteresting; and 58.9% indicated that they 'partially' like chemistry and have a generally positive attitude toward the subject. This indicates a lack of strong motivation (Fig. 1). We were curious to learn about the emotions students associate with chemistry. Most often, chemistry is associated with curiosity – 55.2%, especially for seventh-graders who have just started studying chemistry, fear – 26.5%, related to the subject's difficulty, some students feel bored during lessons – 9.6% and other emotions mentioned by students include surprise, sadness and others (Fig. 2).

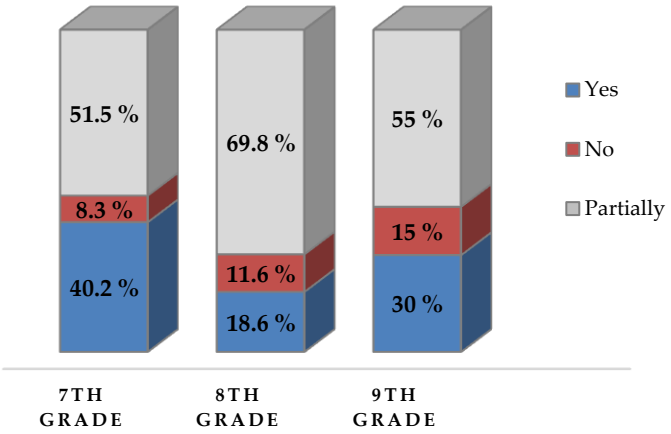

Fig. 1. Pupils' answers to the question: "Do you like studying chemistry?"
Source: author's development

There is a common stereotype that chemistry is overly complicated. This stereotype is one of the factors contributing to the difficulties students face in learning chemistry. During the survey, we found that 65% of ninth-grade students, 55% of eighth-grade students, and 35% of seventh-grade students consider chemistry to be more challenging than physics or biology. Overall, 30% of respondents believe chemistry is difficult due to the terminology and concepts, while 25% attribute the difficulty to formulas and chemical tasks. Although 52% of students know the systematic and trivial names of substances, they do not always distinguish between them. Let us analyze this situation. In almost every chemistry lesson, one or more new concepts are introduced, many of which (such as atoms, molecules, or electrons) cannot be seen or physically experienced, making them difficult to imagine. For example, seventh-grade students are expected to master 46 chemistry concepts (19 of which are theoretical) and learn the names and symbols of at least 20 chemical elements. The large volume of new terms, symbols, and formulas places a significant cognitive load on students' memory.

Responding to the question "*Which topics in chemistry do you find the most challenging?*" students identified the following: "Atomic structure", "The periodic table of chemical elements" (8th grade), "Solutions" and "Redox reactions" (9th grade). The greatest difficulties arise when balancing redox reaction equations (48.1%), completing the reactants and products in reaction chains (35%), solving problems related to "Solutions" (18.5%), and tasks and exercises on atomic structure, the periodic law, and the periodic table of elements (14%). Other challenges were mentioned by 20% of students. Chemical reactions may seem complex to students due to their multi-step nature and the need to memorize formulas. For example, in the transformation sequence $Zn \rightarrow ZnO \rightarrow ZnCl_2 \rightarrow Zn$, based on the fundamental principles of atomic-molecular theory, students must conclude that atoms are conserved during chemical reactions. However, they sometimes struggle to grasp this concept and to understand that the essence of a chemical reaction lies in the rearrangement of atoms. To help students overcome these challenges, we conduct experiments to demonstrate the concepts, as theory alone can seem dry and difficult to comprehend without practical application. Calculations involving molar masses, the quantity of substance based on known mass, volume, number of molecules (structural units), or concentrations can also cause anxiety, particularly among students who lack confidence in their mathematical skills. Responding to the question "*Do you experience difficulties solving chemistry problems and exercises?*" over 25% of students indicated that they face challenges, 72% reported occasional difficulties, and only 11% found it relatively easy (Fig. 3).

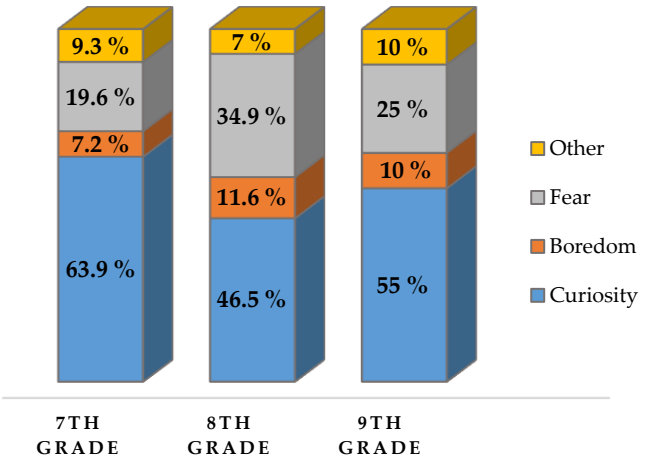

Fig. 2. Pupils' opinions on emotions related to chemistry

Source: author's development

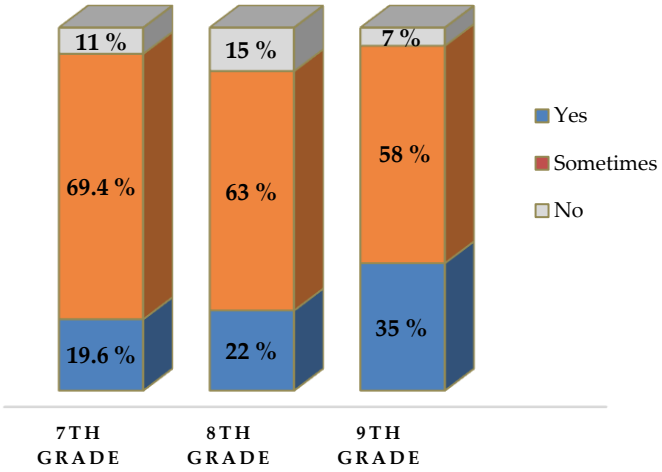

Fig. 3. Pupils' answers to the question: "Do you have any difficulties in solving chemistry problems and exercises?"

Source: author's development

The ability to write and balance chemical equations, solve calculation problems and exercises, as well as tackle complex tasks, is a crucial factor in students' academic success. These skills promote conscious assimilation of chemical knowledge, foster logical thinking, and enhance cognitive development.

Motivational factors that create challenges in learning chemistry are often tied to students' internal beliefs and attitudes toward the subject. For instance, a lack of interest may stem from insufficient integration of the learning material into everyday life. If students fail to see the connection between chemistry and daily life, their interest diminishes, leading to a perception that the subject is irrelevant. In response to the question, "*Do you think chemistry is necessary in everyday life?*", 15% of students believe that chemical knowledge can be practically applied in daily life, over 60% see only partial usefulness, and 25% consider it insignificant and fail to see any practical benefit. It is fair to acknowledge that a significant portion of the material studied in school may not be directly applicable in real life. However, when students perceive a strong connection between the learning material and their daily lives, they grasp it more easily. Conversely, if they do not understand its practical application, their motivation to engage in the subject declines. By connecting educational material to everyday life (food, cosmetics, art,

or ecology), we make it not only more interesting but also more accessible to students, which is the real solution to the problem.

According to the results of the survey, approximately 60% of students believe that chemistry is closely related to other subjects, including physics, mathematics, and biology, while approximately 40% said that there is no such relationship (Fig. 4). This is worrying and may indicate that secondary school students do not understand the natural science component of chemistry.

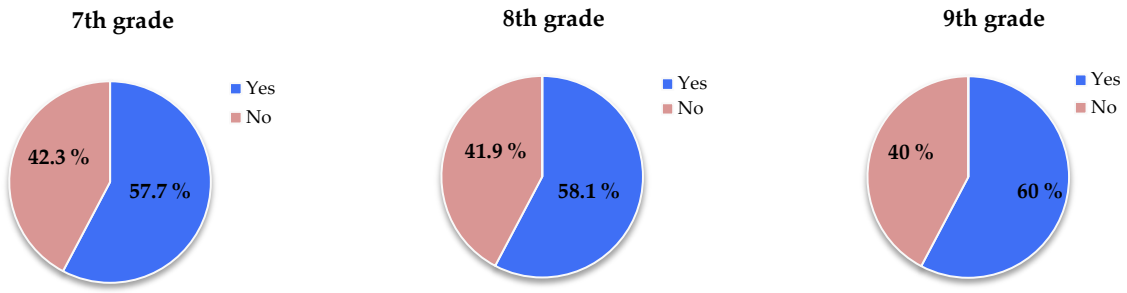

Fig. 4. Pupils' opinions on the relationship between chemistry and other subjects
Source: author's development

Therefore, a positive attitude toward the subject depends on its relevance and interest to students, their understanding of the connections between the subject and real life, its significance for society and individuals, as well as the clarity and accessibility of the material presented.

Another significant factor that creates difficulties in learning chemistry and reduces students' interest is the poor material and technical base of school chemistry rooms. Many schools have limited funding, so demonstrations, laboratory experiments, or practical work are conducted rarely or only formally. This is a significant loss of a powerful tool for engaging students – the student chemical experiment. Figure 5 shows students' opinions on the practical (experimental) component of the lesson. Approximately 75% of students would like to increase it. We believe that one of the ways to solve this problem and to make students more interested in learning chemistry is to use experiments in applied chemistry and virtual chemical experiments.

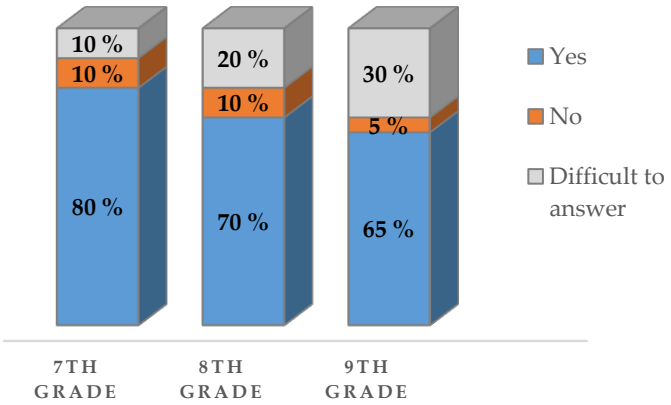

Fig. 5. Students' opinion on increasing the practical (experimental) component of the lesson
Source: author's development

Studying chemistry sometimes becomes merely a process of memorizing formulas and rules. The monotony of material presentation and the lack of an interactive approach to learning complicate understanding and diminish interest in the subject. Modern students prefer interactive methods that help

overcome learning difficulties; however, over 30% still favor traditional lessons with teacher explanations, which aid in understanding complex topics. Figure 6 shows students' responses to the question, "*Would you like computer programs or applications to be used more in chemistry lessons?*".

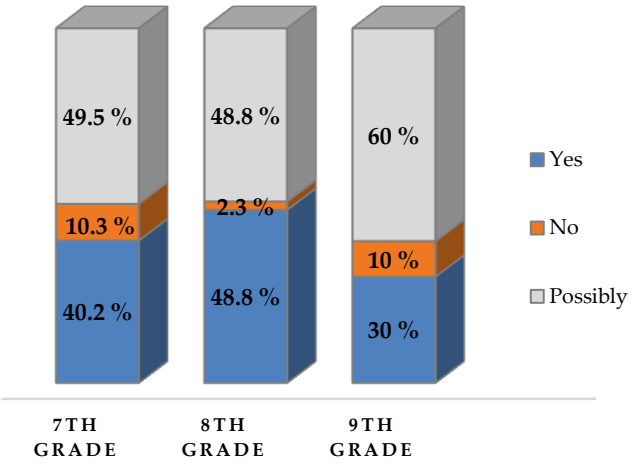

Fig. 6. Students' opinions on the use of computer programs in chemistry lessons
Source: author's development

An effective research method involves an individual's assessment of certain personal qualities. In the context of our study, the self-assessment by secondary school students of their level of chemical skills helped identify the difficulties they encountered in learning chemistry. The students' self-evaluation of their level of skills and knowledge in chemistry revealed that a low level was reported by 13% of 7th-grade students, 23% of 8th-grade students, and 5% of 9th-grade students. A sufficient level was reported by 45%, 54%, and 5%, while an average level was observed in 35%, 20%, and 85% of students, respectively. A high level ranged from 7% to 5%. We hope that the high level of chemical skills and knowledge among secondary school students will continue to improve.

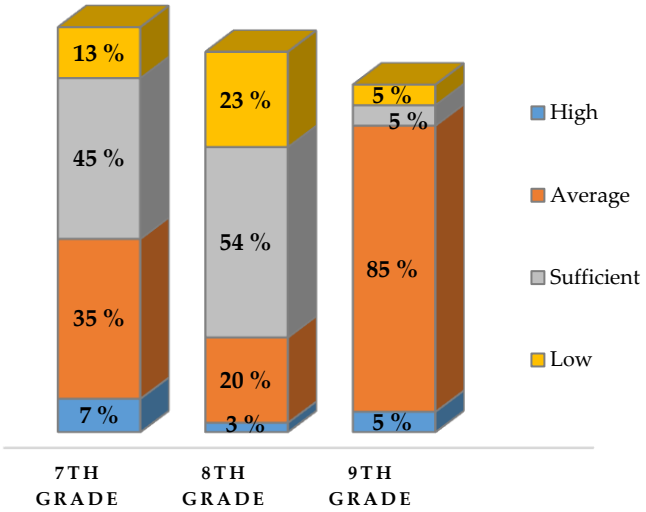

Fig. 7. The level of formation of skills and knowledge in chemistry according to the self-assessment of secondary education students

Source: author's development

4. CONCLUSIONS

The survey results identified the main challenges hindering the successful acquisition of chemistry material: low motivation, the complexity of the material, a lack of awareness of chemistry's practical

relevance, and emotional barriers. Solving these problems requires a comprehensive approach that will increase interest in chemistry and improve students' results.

Firstly, the practical component of learning should be strengthened. Demonstrate the practical benefits of chemistry by connecting topics from the school chemistry curriculum to current real-world problems and their solutions: water purification, assessing food safety, producing natural and eco-friendly cosmetics, exploring hydrogen energy, etc. Secondly, make learning more accessible. Explain complex concepts using analogies or metaphors, and maintain interest through interactivity: incorporate virtual experiments, gamified learning technologies, computer programs, and educational platforms. Thirdly, foster a supportive and friendly classroom atmosphere to reduce fear and uncertainty when facing seemingly challenging topics or tasks. Encourage students by praising their achievements rather than punishing their mistakes. Motivated students are better equipped to overcome difficulties and view chemistry as a source of interesting knowledge rather than a subject full of challenges.

The prospects for further scientific research lie in the study of virtual digital laboratories for conducting experiments in chemistry lessons, as well as platforms for establishing active communication in groups in online and offline formats.

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У статті проаналізовано найважливіші теоретичні та методичні аспекти вивчення хімії у закладах загальної середньої освіти. Для глибшого розуміння труднощів, які виникають у здобувачів середньої освіти під час вивчення хімії, проведено констатувальний експеримент. Анонімно здійснено опитування учнів 7–9 класів СЗШ № 67 м. Львова (Україна). Результати констатувального експерименту засвідчили, що основними труднощами, з якими стикаються учні, є низький інтерес до предмету, складність для розуміння деяких понять і теорій, недостатній зв'язок із практичним застосуванням у реальному житті. З'ясовано, що 65% учнів 9-х класів, 55% учнів 8-х класів та 35% учнів 7-х класів, вважають хімію складним предметом (складнішим, ніж фізика чи біологія). Виявлено, що найчастіше хімію асоціюють із цікавістю – 55,2%, страхом – 26,5%, деякі учні відчувають нудьгу під час уроків – 9,6%, серед інших емоцій учні зазначили: здивування, сум тощо. Досліджено: приблизно 60 % учнів вважають, що хімія тісно пов'язано з іншими предметами, зокрема, фізикою, математикою, біологією, приблизно 40 % зазначили, що такого взаємозв'язку немає; 15 % школярів вважають, що хімічні знання реально можна використовувати у повсякденному житті, понад 60 % вбачають у ній лише часткову користь, а 25 % - не вважають цей предмет особливо значущим, не бачать практичної користі для його вивчення. Приблизно 75% школярів хотіли б збільшити практичну (експериментальну) складову уроку. За результатами опитування, самооцінювання учнями рівня сформованості їхніх умінь і знань з хімії засвідчило, що низький рівень мають 13% семикласників, 23% восьмикласників і 5% дев'ятикласників. Вияв достатнього рівня становив 45%, 54% і 5%, а вияв середнього 35%, 20% і 85% відповідно. Наведено практичні рекомендації для вирішення труднощів, які часто виникають під час вивчення хімії, та підвищення якості освітнього процесу.

Ключові слова: освітній процес, заклад загальної середньої освіти, здобувачі середньої освіти, вивчення хімії, інтерактивні технології.