

SECTION 4. CHEMISTRY

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4.1 The feasibility of holding chemistry tournaments for high school students

The conditions of modern scientific and technological progress and increased competition in the global labor market are placing new demands on the education system in Ukraine. One of the priority tasks is the timely identification, development, and support of gifted children, as they will form the basis of Ukraine's scientific potential in the coming decades. Holding various extracurricular events involving schoolchildren, such as academic competitions, intellectual contests, and „HACKATONS”, are promising and effective mechanisms for achieving this goal. Today, chemistry competitions are of considerable importance in Ukraine, especially for students in grades 10–11, as this age is critical for professional determination and the formation of scientific interests. Therefore, holding intellectual competitions and „HACKATHONS” can have an additional positive impact on the desire of future applicants to choose chemistry-related professions.

The purpose of this document is to justify the need for the systematic holding of chemistry Olympiads, intellectual chemistry competitions, and „HACKATHONS” among high school students, to predict and describe educational, upbringing, and socio-political factors, to identify problems that hinder the development of the Olympiad movement and the possibility of holding intellectual competitions and "HACKATHONS," and to offer practical recommendations for improving the organization and accessibility of such competitions. Therefore, the following factors can be identified that have a certain impact on the possibility of holding such events [107]:

1. *Historical and international aspects of chemistry Olympiads.*
2. *Structure and formats of chemistry competitions for Ukrainian schoolchildren.*
3. *Educational benefits of holding chemistry competitions.*

4. *Development of research skills of Ukrainian schoolchildren through experimentation.*
5. *The motivational and psychological impact of scientific chemistry competitions on schoolchildren in Ukraine.*
6. *Career guidance and social mobility of Ukrainian schoolchildren in their final years of school.*
7. *The role of subject teachers (chemists) and the main methods of preparing for student competitions.*
8. *Main existing problems of the modern chemistry competition movement in Ukraine.*
9. *The influence of digital technologies as a tool for expanding access to participation in student competitions.*
10. *Socio-economic benefits for the state in supporting student chemistry competitions.*
11. *The impact of such measures on the socialization of school youth and their awareness of their role in the future of Ukraine.*

The history of physical competitions between people has its roots in ancient times. However, the history of international subject Olympiads began only in the mid-20th century, and the first International Chemistry Olympiad (IChO) was held in 1968 in Prague [108]. Since then, it has become one of the most prestigious school science events, attended by students who see chemistry not only as their favorite subject, but also as a fascinating tool for learning about the world, an opportunity for creative thinking, and a significant first step toward choosing a future career in science or engineering, which are closely related to chemistry.

Participation in various scientific chemistry tournaments allows students to familiarize themselves with the international scientific environment, compare their level of preparation with their peers in Ukraine and other countries, and gain experience working on complex theoretical, practical, and experimental chemistry tasks [107-116].

An analysis of the existing Olympiad and tournament movement in chemistry around the world shows that countries that systematically invest in their development achieve stable results in training highly qualified chemists.

If we consider the structure and format of various chemistry competitions for schoolchildren, it is worth noting that Olympiads usually take place at the school, district (city), regional, national, and international levels. They mainly include theoretical and practical (laboratory) rounds. Theoretical tasks usually involve solving complex problems in inorganic, organic, and physical chemistry, as well as problems in thermodynamics, chemical kinetics, chemical equilibrium, etc. The practical round involves laboratory experiments, analytical measurements, etc., and always takes place in the relevant chemical laboratories of higher education institutions [107-116].

Given the realities of today, the format of chemistry competitions can be in the form of traditional tests, written problems with detailed answers, as well as using modern digital formats — online tests, simulations of laboratory experiments. The latter partially compensate for the lack of equipment in schools, but they cannot completely replace practical work with real substances.

The main educational value of chemistry competitions lies in creating and arguing for certain educational benefits, which consist in promoting in-depth study of the subject of chemistry. Chemistry competitions encourage students to go beyond the school curriculum and introduce them to scientific methodology: posing scientific chemistry problems, constructing relevant hypotheses, conducting chemical experiments, analyzing research results, and formulating scientific conclusions [107-116].

In addition to chemical knowledge, participation in the preparation for chemistry competitions develops certain key competencies in schoolchildren: critical thinking, mathematical literacy, information literacy, and the ability to conduct scientific chemical dialogue. Such important skills will contribute not only to the further successful education of Ukrainian youth in higher educational institutions of Ukraine, but also to their professional choices [115].

Chemistry competitions also contribute to the development of research skills in schoolchildren through experimentation. It is the experimental component of chemistry that makes chemistry competitions unique, as students have the opportunity to practice various methods of chemical analysis. The skills that schoolchildren acquire in conducting and interpreting experiments are an integral part of chemical scientific culture. Participation in laboratory rounds develops laboratory ethics in students, the ability to work competently with instruments, and adherence to safety procedures. Therefore, the practice of laboratory research contributes to the development of interest in chemistry among schoolchildren and the choice of professions related to chemistry [108-111].

It should be noted that participation in chemistry competitions motivates students to work purposefully. Achievements in the form of diplomas, awards, and opportunities to participate in specialized scientific schools and training courses increase students' self-esteem and develop their internal motivation to study chemistry. The process of competition in a healthy format, which is supported by the organizers of chemistry competitions, develops stress resistance, self-control, and time management skills in students. Therefore, for students who have not won high awards in chemistry competitions, support and feedback from mentors and organizers are important.

Holding various chemistry events and the participation of students in them has a significant impact on their choice of future profession. Students who have had a positive experience in scientific chemistry activities are more likely to choose natural science specialties in higher education institutions. This contributes to the growth of the contingent of young specialists in various chemical and technological fields in Ukraine.

Chemistry competitions in Ukraine also promote the social mobility of today's youth: talented children from low-income or remote regions, having received support and scholarships, have the opportunity to obtain higher education and pursue scientific careers [107-116].

The key factor in successfully preparing schoolchildren for chemistry competitions and winning them is the chemistry teacher. Effective methods of preparing students include extracurricular activities, individual consultations, participation in science clubs, and cooperation with universities. Teachers impart not only knowledge to students, but also skills in conducting scientific research, modeling, testing hypotheses, etc.

Given the rapid development of technology, teaching methods should be constantly diversified: problem-based lessons, case studies, laboratory research, and the integration of information technology (chemical reaction simulators, databases, remote lectures by specialists) should be used. This will ensure the development of a wider range of skills in students while studying chemistry [114].

It is also worth noting certain problems in the modern chemistry competition movement that are relevant to chemistry teachers. These include unequal opportunities in preparing students from different regions for chemistry competitions, lack of funding, insufficient laboratory facilities in rural and small schools, and the absence of a regular mentoring system [107-116]. In addition, there is a certain risk of excessive specialization in the current environment, as some students prepare only for chemistry competitions, which may cause them to fall behind in other subjects.

Another problem is of a moral and ethical nature, namely that competition between students sometimes exceeds acceptable limits, with the emergence of practices such as the "commercialization" of preparation (paid courses, tutoring) for chemistry competitions, which limits access for the most talented but financially vulnerable students.

To successfully motivate high school students to study chemistry, the development of online platforms with educational materials, video lectures, interactive laboratories, and test banks can significantly expand access to quality training. Webinars from leading teachers, distance training, and online competitions make it possible to attract students from remote regions. It should be noted that digital resources should complement the educational process, not replace practical or laboratory work. Therefore, the ideal format for chemistry lessons is a hybrid one,

where theoretical training in an online environment is combined with face-to-face practical training [109-116].

Current problems in Ukrainian education can significantly affect the development of chemistry competitions among schoolchildren. Therefore, investing in this area is an investment in the development of future human capital in Ukraine. Supporting gifted young people has long-term prospects and returns: growth in innovative activity, development of applied research, and increased competitiveness of Ukraine's national economy. Continuous encouragement of participation in various chemistry competitions for students from different regions of Ukraine, the creation of grant programs and scholarships for winners are modern and effective tools for implementing our country's state policy in the field of education and science.

Given the existing problems in the desire of high school students to study chemistry-related subjects, certain practical recommendations can be offered to expand and improve student interest through intellectual tournament games and "HACKATHONS" [107-116]:

- ✓ develop a permanent state-level program to support gifted students, including funding for practical tours, the purchase of laboratory equipment for schools, and decent scholarships;
- ✓ create a single centralized online platform with open materials: video lectures, databases of past years' tasks, interactive simulators;
- ✓ develop a network of regional science schools and training centers that can provide face-to-face laboratory courses for talented students from neighboring schools;
- ✓ introduce mentoring programs: cooperation between schools and universities and scientific institutions (joint projects, supervision by scientists);
- ✓ ensure a transparent selection system for national teams, minimizing corruption risks and increasing trust;
- ✓ create mechanisms to reimburse expenses for students from low-income families (travel, accommodation, reagents).

✓ promote chemistry through the mass media, science festivals, demonstration experiment competitions, and social networks.

With some experience in organizing chemistry-related intellectual competitions, the authors have discussed the following plan of recommendations to encourage students to participate in them:

- propose that chemistry teachers assess the basic level of senior students and jointly develop an individual program for each student for further participation in chemistry training;

- combining regular optional chemistry classes (at least twice a week) both at school and in the laboratories of higher education institutions with work on basic chemistry problems and laboratory research;

- conducting intensive courses on theoretical sections of chemistry: thermodynamics, chemical kinetics and equilibrium, etc.

- conducting practical training sessions for schoolchildren by a chemistry teacher to prepare them for school, city, regional, and national chemistry tournaments, intellectual chemistry competitions, and „HACKATHONS”.

- participation in regional chemistry tournaments.

- participation of senior school students in specialized summer science schools in chemistry, which can be organized both at the school and at a higher education institution.

In order to interest students in long-term and frequent participation in organized school tournaments, it is important for organizers to ensure the quality and fairness of their assessment. The proposed criteria should be clear and understandable, first and foremost, to the participants: the correctness of the calculations of the tasks, the logical presentation of ideas, the correctness of the experimental results and their interpretation, etc. The authors recommend creating appropriate open criteria scales for all rounds so that participants clearly understand them and can systematically prepare for subsequent tasks.

The organizers should also take into account the ethical principles of holding various tournaments, with regard to inclusion: equal access for all interested students

studying chemistry to participate in competitions, tournaments, etc.; prohibition of corrupt practices; and correct feedback to participants. Organizers should pay special attention to students with special needs: creating conditions for the participation of students with special educational needs, providing adapted tasks, and mandatory technical support.

Today, many regions in Ukraine demonstrate positive practices in conducting school tournaments, Olympiads, and other competitions with a focus on chemistry: centralized training centers with basic laboratory infrastructure, internship programs for teachers, and active cooperation with universities. In Ukraine, examples of educational institutions that systematically prepare Olympiad participants confirm the effectiveness of combining face-to-face training and distance learning resources. It is worth noting the successful practice of holding a "HACKATHON" at the National University "Lviv Polytechnic." [116] The intellectual competition was organized by the director of the ICCT, Volodymyr Skorokhoda, the head of the ICCT Department of Organic Chemistry, Volodymyr Donchak, and the head of the ICCT Department of Physical, Analytical and General Chemistry, Pavlo Shapoval. The coordinators of the competition were ICCT lecturers Roksoliana Bukliv, associate professor of the Department of Chemistry and Technology of Inorganic Substances, and Olha Budishevskaya, professor of the Department of Organic Chemistry, associate professors of the Department of Physical, Analytical and General Chemistry Lilianna Oliynyk and Zoryana Komarenska, did their utmost during the event to encourage students to study chemistry and demonstrate their quick wits and intellect.

Student volunteers Vladyslava Novosad and Vladyslava Zhuk provided great assistance in preparing and organizing the competition, while Oleksandra Bondar and Olga Burets also took part in conducting the competition. Together with the teachers of Lviv Polytechnic National University, the leaders of the Lviv Regional Small Academy of Sciences for Schoolchildren, Svitlana Kernichna and Maria Ostapiuk, worked on compiling the competition tasks.

The following competitions were offered to tournament participants:

1. Rules for working in a chemical laboratory (1 point each, 12 points, 5 minutes).

2. Laboratory equipment (1 point each, 12 points, 5 minutes).
3. Chemical erudition (1 point each, 10 points, 10 minutes).
4. Chemistry crossword puzzle (1 point each, 9 points, 5 minutes).
5. Chemical rebuses (2 points each, 12 points, 10 min).
6. Pictures of substances (1 point each, 12 points, 5 minutes).

In the first contest, the participants of the "HACKATHON" had to answer YES/NO to the following questions:

✓ When preparing an acid solution, water should be added to the acid in small portions.

Answer: NO.

✓ After conducting experiments, the remaining reagents should be poured down the sink.

Answer: NO.

✓ You should not eat while conducting experiments.

Answer: YES.

✓ Do not stir solutions with your finger.

Answer: YES.

✓ When heating, do not point the opening of the test tube at yourself; point it at your neighbor.

Answer: NO.

✓ Dry substances are collected with a spatula, and wet substances are scooped up with a beaker.

Answer: NO.

✓ When stirring a solution, do not cover the opening of the flask with your finger.

Answer: YES.

✓ Do not look at the substances in the test tube opening during heating.

Answer: YES.

✓ When heating substances in a test tube, only the area where the substance is located should be heated.

Answer: NO.

✓ Do not work with volatile substances near open flames.

Answer: YES.

✓ To determine the smell of a substance, bring the container with the substance close to your nose and inhale deeply.

Answer: NO.

✓ After conducting experiments, wash your hands.

Answer: YES.

The second contest involved correctly identifying the names of laboratory equipment:

- ✓ Test tubes.
- ✓ Measuring cylinder.
- ✓ Conical flask.
- ✓ Mortar and pestle.
- ✓ Test tube holder.
- ✓ Tripod foot.
- ✓ Tripod.
- ✓ Round-bottom flask.
- ✓ Gas burner.
- ✓ Burette.
- ✓ Measuring cup.
- ✓ Alcohol lamp.

In the "Chemical erudition" competition, teams of schoolchildren had to give the correct answers to the following questions:

✓ What is the name of the spontaneous process of metal oxidation in air?

Answer: corrosion.

✓ What is the smallest particle of a substance that carries the properties of that substance?

Answer: molecule.

✓ What is "black gold"?

Answer: petroleum.

✓ What substance is called "dry ice"?

Answer: carbon(IV) oxide.

✓ What color does litmus indicator turn in an acidic environment?

Answer: red.

✓ What is the formula of the main substance in chalk?

Answer: CaCO_3 .

✓ What is the name of the layer in the atmosphere that plays a significant role in preserving life on planet Earth?

Answer: ozone layer.

✓ What acid is used as a flavoring agent for preserving and pickling vegetables?

Answer: acetate (acetic, ethanoic) acid.

✓ What acid is found in gastric juice?

Answer: hydrochloric acid.

✓ What substance did Leonardo da Vinci call the "juice of life"?

Answer: water.

In the "Chemical Crossword puzzle" task, students had to fill in the horizontal rows with the names of nine elements, whose symbols are depicted in circles around the crossword (one letter per cell). Then, they had to write their names horizontally in the " " so that the surname of the scientist who created the symbols for the chemical elements could be read vertically in the cells highlighted in red.

The "Chemical rebuses" contest involved guessing the chemical name from a picture. To do this, in the cells under each rebus, it was necessary to guess and write the name of a chemical element or simple substance: write the names of objects and animals in a row, a comma above the image meant to cross out one letter.

The "Pictures of substances" task included 12 slides with corresponding images and questions, which are listed below:

- ✓ This metal is in a liquid state at room temperature.

Answer: mercury.

- ✓ A product made from this bloodiest metal in history could have cost Archimedes his head.

Answer: gold.

- ✓ The only substance that has a purely salty taste.

Answer: sodium chloride.

- ✓ This gas is responsible for the smell of rotten eggs.

Answer: hydrogen sulfide.

- ✓ Dihydrogen monoxide is the official name of this substance. According to a popular saying, you can drown in a spoonful of this substance.

Answer: water.

- ✓ The absence of this simple substance would lead to the destruction of life on Earth from ultraviolet rays.

Answer: ozone.

- ✓ The name of this gas translates as "sunny".

Answer: helium.

- ✓ In ancient times, this metal was called "heavenly copper." Until people learned how to extract it, they had to wait for it to fall from the sky.

Answer: iron.

- ✓ One drop of this substance kills a horse.

Answer: nicotine.

- ✓ This metal shortened the lives of the inhabitants of Ancient Rome.

Answer: Pb.

- ✓ This substance does not burn, but it can be extinguished with acid.

Answer: baking soda.

- ✓ Insects use this substance to kill their victims.

Answer: formic acid.

The competition took place in a creative and friendly atmosphere. The teams of students actively discussed the answers to the competition questions.

At the end of the intellectual competition, the participating teams were awarded diplomas in various categories and souvenirs.

Considering the above, it should be noted that holding chemistry tournaments, in particular intellectual competitions and "HACKATHONS" for students in grades 10–11, is a very significant contribution to the development of education in Ukraine, which will contribute to improving the quality of chemical knowledge and the development of scientific chemical thinking, and thus to the formation of human resources and the enhancement of Ukraine's international prestige. To achieve the greatest effect, it is advisable to systematically support the chemical tournament movement in various formats and invest in the chemical laboratory infrastructure of educational institutions, develop existing online resources, and create real support programs for talented chemistry students and their mentors. According to the authors, the implementation of the proposed recommendations will ensure the accessibility and quality of preparation for chemistry competitions, promote the wider involvement of students from different regions and social groups in such events, and strengthen the role of chemistry as a key element of science education in the future development of Ukraine.