Ihor Chernetskyi,
Candidate of Pedagogical Sciences, Head of the Department
Creation of Educational and Thematic Knowledge Systems,
National Center "Junior Academy of Sciences of Ukraine",
Kyiv, Ukraine

https://orcid.org/0000-0001-9771-7830

Oksana Vilchynska,
Candidate of Economic Sciences,
Associate Professor,
Associate Professor of the Department of Statistics
Ivan Franko National Univesity of Lviv,
Lviv, Ukraine

https://orcid.org/0000-0002-4544-4751

Iryna Slipukhina,
Doctor of Pedagogical Sciences, Professor, Chief researcher,
National Center "Junior Academy of Sciences of Ukraine";
Institute of the Gifted Child of the NAES of Ukraine,
Kyiv, Ukraine

https://orcid.org/0000-0002-9253-8021

UDC 37[4.31+018.2/.43+013.31]:614.44
DOI: https://doi.org/10.63437/3083-6425-2025-4(99)-10

STATISTICAL CHARACTERISTICS OF THE ALL-UKRAINIAN ONLINE TOURNAMENT "OPEN NATURAL SCIENCE DEMONSTRATION"

Summary.

This article presents the results of a study of the All-Ukrainian Internet Tournament in Natural Sciences "Open Natural Science Demonstration", which examines its use as a tool for informal science education and the development of gifted students. The results of teams' participation in the tournament between 2015 and 2021 were analysed to identify the subject-specific factors influencing the variability of participants' academic achievements and the role of tournament events in the development of key research and STEM competencies. The research methodology consists of descriptive statistics, variance analysis, and comparative analysis of team results in different categories (prize winners, laureates, and participants without awards). Statistically significant differences in average scores were found depending on the subject area. Physics and chemistry tasks have the greatest impact on the final results of teams, while results in astronomy, biology, and geography are relatively stable in most cases. The study shows that the level of development of physics and mathematics competencies is a key factor in differentiating teams based on tournament results, especially when distinguishing between prize-winning teams and laureate teams. The educational potential of using video, computational and research tasks to develop critical thinking, interdisciplinary integration of knowledge and a culture of research among students in distance and blended learning has been demonstrated. The results obtained can be used to improve the content of informal science education, develop educational competitions for gifted young people, and improve the quality of science teaching in general secondary schools.

Keywords: scientific education; informal education; gifted students; online tournament; natural sciences; STEM education; research activities; video tasks; interdisciplinary integration.

Statement of the problem. In today's educational landscape, academic competitions for pupils and students play a unique role in recognising academic excellence, nurturing intellectual potential, and cultivating interest in scientific research. In Ukraine, such competitions have historically taken several established forms, each reflecting a particular educational philosophy and approach to assessment and participant requirements.

The most common are theoretical competitions, such as subject-based Olympiads, which traditionally focus on individual participation and completing tasks under strict time constraints with a partial or complete ban on using additional sources of information. In these competitions, participants' ability to quickly analyse tasks, visualise abstract models of phenomena, and apply algorithms developed during preparation is crucial. Success in these tasks depends not only on knowledge, but also on psychophysiological factors such as stress resistance and the ability to think intensively and independently.

Complex Olympiads, in which participants simultaneously solve problems from several related subjects, occupy a special place within the framework of theoretical competitions. These competitions encourage interdisciplinary thinking while preserving the autonomy of task performance. In accordance with their philosophy, they do not allow for the public presentation of solutions. It is also worth noting that, within the existing educational model, the results of Olympiads are often seen as an indicator of an educational institution's effectiveness, which gives participants from specialised schools, where individual subjects are studied in depth, an advantage.

Another approach to organising scientific competitions is represented by practical competitions, which are usually team-based and involve extensive preliminary research and the presentation of results in a reasoned manner. These events, known as tournaments, resemble the real scientific process in that they combine problem-solving, solution-seeking, public defence and scientific discussion. However, a significant obstacle to widespread participation in practical tournaments is the dependence of task performance quality on the educational institution's material and technical resources, as well as the single-subject nature of most proposed research.

In response to these limitations of the educational environment, mixed forms of scientific competition are becoming increasingly popular. These combine elements of Olympiads and tournaments and have a multi-stage structure with different conditions for passing each stage. Experience from around the world shows that these formats are the most effective way to engage students broadly in understanding the logic of scientific research, forming research competencies and developing interdisciplinary thinking. Mixed competitions usually focus on direct participation and are becoming an increasingly popular tool for informal and non-formal scientific education.

Analysis of recent research and publications. The European Olympiad of Experimental Science [1] is one of the practical competitions held in the European Union. Pupils and students from EU countries who are no older than 17 at the time of the Olympiad take part in this practical competition. The Olympiad involves team participation. No more than two teams are permitted from each country. Teams are formed on the basis of national selections. The competition consists of teams conducting two small studies according to clear instructions. The essence of the study involves carrying out laboratory work on a specific object, examining its chemical, biological and physical properties. Participants are only allowed to use the equipment available in the laboratory when conducting research. Teams are not given advance knowledge of the tasks. The results of the teams are recorded on special forms. Assessment is carried out according to the criteria specified in a special document. According to their website, the purpose of the Olympiad is to encourage young people in the European Union who aspire to pursue scientific careers to engage with scientific education.

The International STEM Olympiad [2] is one of several international theoretical competitions that take place remotely throughout the year. It covers mathematics, natural sciences, computer science and the arts. It is open to students of all ages from any country. It takes the form of solving specific sets of multiple-choice questions. It is an individual competition. There is a fee to participate. Participants must have their video cameras turned on. The competition has several stages, and participants receive a certain number of points at each stage, allowing them to progress to the next one. The final stage, called “Best of the Best”, awards participants with an electronic certificate of achievement and a gold medal. Participants are encouraged to use simulations of natural phenomena and a programme for visualising mathematical functions when solving problems in mathematics and natural sciences. The competition aims to motivate students of different age groups to study the STEM subjects included on the list of basic disciplines.

Another example of a practical competition is the International Simulation Olympiad™ [3]. This international competition is dedicated to promoting the modelling of physical processes using computers. The competition uses open-source software. University students can participate in the Olympiad either individually or in teams. Tasks are divided into three categories: multiphase flows, aerodynamics and thermal engineering. Each task requires confirmation of experimental data using computational modelling and is assessed on an 8-point scale. While the use of network and human resources is permitted to solve the tasks, the final submission must be the team's own original work. The top three teams will receive cash prizes.

Weizmann University (Israel) holds an interesting international tournament called Safe Cracking [4], which is open to teams of students from different educational institutions. The tournament involves teams of students from different educational institutions in the creative design of scientific exhibits (safes), which other participants then attempt to open. Over the course of a year, each team of several participants develops two related physics experiments that can be carried out in a locked space (safe), and then builds the exhibit. The other teams are given a story related to the idea behind the experiments. Using this, they must guess the sequence of actions required to obtain the key to the safe. Additionally, all team members are interviewed by the organisers of the tournament to assess their basic knowledge, as demonstrated by their safe. As a result, winners and prize-winners are determined in several categories. The age limit for participants is determined by the senior school. The tournament usually brings together up to 50 teams from around the world. This is a direct participation tournament.

An example of a creative international environmental Olympiad with individual participation is the International Environmental Project Competition “GENIUS Olympiad” [5]. The competition was founded by the non-profit organisation Terra Science and Education in 2011, and since 2020, the Rochester Institute of Technology has been a permanent partner of the event. In 2021, the Ukrainian Academy of Sciences became the official and sole representative and organiser of the GENIUS Olympiad in Ukraine. Participants submit their work in various sections: Science, Robotics, Business, Creative Writing, Art, Music, or Short Film. Regardless of the category, the project must be related to ecology. According to the results of registration in 2020–2021, the MAN became the second institution in the world to submit the most projects for international qualification – 42. And in 2022, with a result of 51 awards, Ukraine took third place among all countries represented by contest participants in terms of the number of awards received at the GENIUS Olympiad Global.

Another example of a practical competition designed to foster creativity is the Destination Imagination programme [6]. This competition forms part of the learning process for students of all ages. It is a team competition with regional selection levels. Teams consist of five to six participants of the same age. Teams are given tasks in the form of challenges. Each challenge is a concise proposal for a project and its presentation. The team chooses one of four categories: Scientific, Artistic, Improvisational or Social. For the scientific challenge, teams must use their scientific and engineering knowledge to create and present a specific prototype. In addition to long-term tasks, there are short-term challenges, the details of which are only revealed to the team during the presentation. The competition final takes the form of a large science show in the United States.

An analysis of current international and national academic competitions reveals significant diversity in the formats used to organise educational and research activities for pupils and students, ranging from theoretical Olympiads to practical and mixed tournaments designed to develop experimental, research and creative competencies. However, most of these events have clear restrictions regarding the age of participants, the subject focus, the forms of participation, and the material and technical conditions required to complete tasks. This limits their potential as tools for informal scientific education.

In contrast to the aforementioned models, the All-Ukrainian Internet Tournament in Natural Sciences, “Open Natural Science Demonstration” (ONSD), incorporates an interdisciplinary approach, team interaction and the use of video, computational and research tasks, while also embracing the principle of open access to information resources [7]. This attracts a wide range of participants, regardless of their educational institution's resources, and allows the educational potential of the tournament to be realised in distance and blended learning contexts.

Despite the long-standing tradition of holding the ONSD and its prevalence in the informal education system, scientific publications do not provide sufficient systematic quantitative analysis of the results of team participation, particularly with regard to subject areas and participant categories. This necessitates the use of statistical methods to identify factors influencing variation in academic achievement and to demonstrate the pedagogical relevance and effectiveness of the tournament in developing STEM competencies.

The article aims to analyse the results of teams' participation in the ONSD, an All-Ukrainian Internet tournament in natural sciences, to identify subject-specific factors that determine participants' academic achievements. It also seeks to assess differences in results between different categories of teams and substantiate the educational potential of the tournament as a tool for informal science education in the context of distance and blended learning.

Research methodology. The empirical basis of the study was the anonymised results of the tournament tasks performed by participating teams at the qualifying and main stages of the competition. These results were presented in terms of subject areas (physics, astronomy, biology, geography and chemistry) and team categories (prize winners, laureates and participants without awards).

Initial data processing involved collecting, grouping and summarising statistical information, enabling distribution series of average scores for individual disciplines and tournament years to be formed. To visualise the results, data visualisation methods (tabular and graphical forms) were employed.

Quantitative indicators were analysed using descriptive statistics, particularly the calculation of average values and analysis of variation in results within groups of participants.

To test the working hypotheses regarding statistically significant differences in average scores between subjects and team categories, analysis of variance (ANOVA) was employed. One-factor analysis of variance was used in particular to assess the impact of the subject area on the team's average score, as well as to compare the results of the winning teams, laureates, and teams that did not receive awards. The level of statistical significance was set at $p = 0,05$.

We used comparative analysis to interpret the results, which helped us identify which subjects had a significant impact on the final team rankings and track changes in average scores over time.

These methods were applied with consideration for the specifics of the tournament as a form of informal scientific education, particularly the conditions of distance and blended learning, and the peculiarities of the task structure (qualitative, computational, and research).

Results and discussion. Let's take a look at ***the history of the creation and organisation of competitions.*** The ONSD is a nationwide competition for students in Years 7–11. It aims to engage schoolchildren in active cognitive and research activities in the field of natural sciences. The tournament's main goal is to popularise science and deepen students' knowledge of physics, chemistry, biology, geography and astronomy, while also developing their teamwork, information literacy and critical and creative thinking skills.

Launched in 2010, the tournament has been held annually ever since, attracting around 2,000 schoolchildren from various regions of Ukraine each year. Over the years, a stable educational community of participants, team leaders and experts has formed, bringing together dozens of general secondary, extracurricular and pre-higher education institutions. Scientists and distinguished teachers from Ukraine sit on the tournament jury, ensuring a high level of expert evaluation and providing scientific and methodological support for the competition. The project is organised by the National Centre "Junior Academy of Sciences of Ukraine" (NC JASU) [8] and the All-Ukrainian public organisation "Association of Physics Teachers «Path of Education – XXI»", with direct implementation carried out by employees of the relevant departments and educational laboratories of the NC JASU [9].

The tournament involves teams of 5–6 students from schools, colleges and other educational institutions, each led by a member of teaching staff. Held annually from September to December, the tournament covers five subject areas: physics, astronomy, biology, geography and chemistry.

The competition consists of two rounds: a qualifying round, which is remote, and a final round, which is face-to-face. Tasks in the qualifying round are based on video recordings of natural phenomena, laboratory experiments and computer models, creating conditions that combine visualisation, analytical thinking and independent problem solving. The qualifying round consists of two stages. In the first stage, teams are given 20 video tasks (four from each subject area) and have a month and a half to complete them. The main stage involves solving a similar number of tasks in one day, and teams that have scored at least 75 % of the maximum possible points are admitted to it. Based on the results of this stage, the three teams with the highest scores advance to the final.

The final stage traditionally involves a face-to-face meeting of teams in Kyiv. During the final round, teams take turns to solve five tasks, one from each subject area, with a time limit of five minutes for each task. These tasks combine video clips with live demonstrations and experiments conducted directly in the auditorium.

The tournament is clearly educational in nature. While completing the tasks at all stages, participants can use any information sources, including the internet. However, the conditions of the tasks are such that there are no ready-made answers in the public domain. This encourages teams to analyse various information resources, develop their own reasoning, and draw well-founded conclusions. Although there is no formal appeals process, participants can discuss the results with the jury members after receiving their scores. The winners, prize-winners and overall winner are determined based on the results of the tournament; finalists receive appropriate diplomas and awards, and participants of the main stage receive laureate diplomas. Due to external circumstances, the final of the tournament was held online in 2020–2022.

Developing the tournament format to adapt to changing educational conditions has led to tasks gradually becoming more complex and their research component being strengthened. This was in response to the demand for students to develop deeper subject-specific and interdisciplinary competencies, and to the challenges of distance and blended learning.

Starting in 2020, calculation tasks were incorporated into the structure of the examinations, and in 2021, research tasks were introduced. These tasks are presented in the physics, chemistry, biology and astronomy sections. Given wartime conditions and the adoption of blended learning, these tasks are designed to be completed using either computer resources or the simplest available equipment.

Examples of research tasks include:

– Physics: studying the dependence of the stiffness of an elastic system formed by a chain of rubber bands on the number of elements in the chain; developing a measurement methodology; constructing corresponding graphical dependencies; and formulating conclusions.

– Biology: identification and quantitative assessment of cattle herds based on satellite images from Google Earth with specified geographical coordinates; analysis of the spatial distribution of objects; and interpretation of the obtained data.

– Astronomy: development of a methodology for determining the level of light pollution in the night sky using visual observations, digital images, or open online resources; analysis of the results; and summarisation.

Let's look at the ***statistics on the results*** achieved by teams between 2015 and 2021. According to the results of the exploratory analysis *(Table 1),* we see that during the study period (2015–2021), the lowest average scores were received for tasks in physics (1,59) and chemistry (2,2).

Table 1

Average grades by subject

	Physics	Astronomy	Biology	Geography	Chemistry
2015	1,14	3,11	3,93	-	-
2016	1,99	3,67	3,61	4,17	2,90
2017	1,11	2,50	3,27	3,62	1,98
2018	1,52	2,97	4,31	4,07	2,07
2019	1,68	2,18	3,05	3,79	1,77
2020	2,38	2,39	2,84	4,49	2,35
2021	1,31	2,83	2,64	3,45	2,14
Average value	1,59	2,81	3,38	3,93	2,20

Source: own calculations.

For a more detailed analysis, we will work on a working hypothesis about the influence of the subject on the average grade, with a null hypothesis about the absence of statistically significant differences in grades for different subjects.

For a more detailed analysis, we will work with a working hypothesis about the influence of the subject on the average grade, with a null hypothesis about the absence of statistically significant differences in grades for different subjects.

Based on the variance analysis, at a signifi cance level of 0,05, we reject the null hypothesis (F(0,05; 4; 28) = 2,71 < F = 24,03), i.e. with a probability of 95 %, we can speak of statistically significant differences in grades for different subjects, with 69,96 % of the variation in grades being due to the variation in subjects.

Table 2 presents pairwise comparisons of average grades for subjects.

The variance analysis results presented in *Table 2* indicate that different subject areas have an unequal impact on teams' final results at the qualification stage. In particular, the average scores for physics differ significantly from those for astronomy, biology and geography at a significance level of p = 0,05 when compared pairwise. This suggests that physics tasks are characterised by significantly lower average scores compared to most other subjects, and consequently have the greatest negative impact on teams' total scores at the qualification stage. Conversely, a comparison of the average physics and chemistry scores revealed no statistically significant differences, suggesting a similar level of complexity or difficulty in these two disciplines for the tournament participants. Similarly, there were usually no statistically significant differences between the scores in astronomy, biology, and geography, suggesting a relatively consistent level of performance in these subjects. Thus, the data in *Table 2* confirm that physics (and to some extent, chemistry) is a key factor in differentiating teams' results at the qualification stage. These disciplines most determine the variation in final scores and cause the stratification of teams by level of success. These results provide a basis for further analysis of the content and structure of physics and chemistry tasks, as well as the more general issue of students' subject competence development.

Let us consider the results of the teams that participated in the main stage. We present the overall results of the teams participating in the main stage *(Table 3)*, broken down into winning teams, laureate teams, and teams that did not receive awards.

Table 2

Summary results of the variance analysis of assessments at the qualification stage

	Subjects / average score	df1	df2	F	F(0.05;df1;df2)		Conclusion on the acceptance/rejection of the null hypothesis
Physics / 1,59	Astronomy /2,8	1	12	21,9	4,7	0,6459	reject
	Biology / 3,4	1	12	38,6	4,7	0,7627	reject
	Geography / 3,9	1	11	85,1	4,8	0,8948	reject
	Chemistry / 2,2	1	11	4,7	4,8	0,3204	**accept**
Chemistry / 2,2	Astronomy / 2,8	1	11	5,6	4,8	0,3399	reject
	Biology / 3,4	1	11	16,7	4,8	0,6035	reject
	Geography / 3,9	1	10	59,8	4,9	0,8567	reject
Astronomy / 2,8	Biology / 3,4	1	12	3,7	4,7	0,2358	accept
	Geography / 3,9	1	11	19,9	4,8	0,4427	reject
Biology/ 3,4	Geography / 3,9	1	12	4,4	4,7	0,2684	**accept**

Source: own calculations.

ISSN 3083-6425 online | ISSN 2309-3935 print

Table 3

Summary results of the variance analysis of the ratings of the teams participating in the main stage

Subjects / average score		df1	df2	F	F(0.05;df1;df2)		Conclusion on the acceptance/ rejection of the null hypothesis
All participants							
Physics / 2,96	Astronomy /4,1	1	12	31,3	4,75	0,6909	reject
	Biology / 4,2	1	12	22,3	4,75	0,6505	reject
	Geography / 4,5	1	12	85,1	4,75	0,8259	reject
	Chemistry / 3,2	1	12	0,68	4,75	0,0543	accept
Chemistry / 3,2	Astronomy / 4,1	1	12	6,8	4,75	0,3634	reject
	Biology / 4,2	1	12	7,2	4,75	0,3740	reject
	Geography / 4,6	1	12	17,3	4,75	0,5900	reject
Астрономія / 4,1	Biology / 4,2	1	12	0,045	4,75	0,0038	accept
	Geography / 4,6	1	12	4,42	4,75	0,2695	accept
Biology /4,2	Geography / 4,6	1	12	2,83	4,75	0,1908	accept
Winning teams							
Physics / 3,997	Astronomy /4,7	1	12	4,72	4,75	0,2825	accept
	Biology / 4,5	1	12	4,07	4,75	0,2531	accept
	Geography / 4,9	1	12	22,1	4,75	0,6479	reject
	Chemistry / 4,3	1	12	1,25	4,75	0,0942	accept
Chemistry / 4,3	Astronomy / 4,7	1	12	4,56	4,75	0,2754	accept
	Biology / 4,5	1	12	1,12	4,75	0,0856	accept
	Geography / 4,9	1	12	4,68	4,75	0,2806	accept
Astronomy / 4.7	Biology / 4,3	1	12	0.59	4,75	0,0472	accept
	Geography / 4,9	1	12	4,41	4,75	0,2689	accept
Biology 4,3	Geography / 4,9	1	12	2,9	4,75	0,1935	accept
Award-winning teams							
Physics / 3,11	Astronomy /4,3	1	12	21,03	4,75	0,6367	reject
	Biology / 4,2	1	12	13,58	4,75	0,5309	reject
	Geography / 4,7	1	12	43,8	4,75	0,7851	reject
	Chemistry / 3,4	1	12	0,51	4,75	0,0408	accept
Chemistry / 3,4	Astronomy / 4,3	1	12	4,72	4,75	0,2824	accept
	Biology / 4,2	1	12	4,53	4,75	0,2741	accept
	Geography / 4,7	1	12	4,73	4,75	0,2828	accept
Astronomy / 4,3	Biology / 4,2	1	12	0,15	4,75	0,0127	accept
	Geography / 4,7	1	12	4,39	4,75	0,2679	accept
Biology 4,2	Geography / 4,7	1	12	4,34	4,75	0,2659	accept
Teams without awards							
Physics / 2.26	Astronomy /3,5	1	12	13,9	4,75	0,5374	reject
	Biology / 3,9	1	12	25,8	4,75	0,6829	reject
	Geography / 3,9	1	12	23,3	4,75	0,6597	reject
	Chemistry / 2,5	1	12	0,45	4,75	0,0377	accept
Chemistry / 2,5	Astronomy / 3,5	1	12	9,5	4,75	0,4408	reject
	Biology / 3,9	1	12	19,1	4,75	0,6143	reject
	Geography / 3,9	1	12	17,5	4,75	0,5927	reject
Astronomy / 3,5	Biology / 3,9	1	12	3,7	4,75	0,0735	accept
	Geography / 3,9	1	12	1,3	4,75	0,0947	accept
Biology 3,9	Geography / 3,9	1	12	0,07	4,75	0,0057	accept

Source: own calculations.

The data presented in *Table 3* enable us to identify differences in the subject composition of teams' academic achievements at the final stage, depending on their outcomes (winning teams, award-winning teams and teams without awards). This allows us to further refine the conclusions obtained at the qualifying stage. Prize-winning teams are characterised by a high and relatively consistent level of preparation across most natural science disciplines. No statistically significant differences were found in the average scores for physics, astronomy, biology and chemistry.

The exception is physics and geography, where higher average scores in geography were recorded. This suggests that physics does not present a 'bottleneck' for winning teams and that their overall high performance is achieved through balanced interdisciplinary competency development. Award-winning teams are characterised by an asymmetrical subject structure of results. They achieve the highest average scores in geography (4.7), astronomy (4.3), and biology (4.2). Slightly lower results in chemistry (3.3) do not cause a statistically significant variation in the overall score. Conversely, the low average score in physics (3.1) has a statistically significant impact on the team's final result, clearly distinguishing the winners from the prize-winners. Teams that did not receive awards in the main stage demonstrate significantly lower average scores in all subjects compared to the winners and prize-winners. However, the distribution of scores in this group generally reflects the trends observed in the qualifying stage: the main variation in the total score is due to the results in physics and chemistry, while the scores in astronomy, biology and geography remain relatively stable.

Thus, the results of the variance analysis presented in *Table 3* confirm the conclusion that physics plays a key role in differentiating between teams in different performance categories. For the winning teams, physics is integrated into their high-level training, whereas for the Award-winning teams and, in particular, the non-award-winning teams, it is physics that determines the boundary between high and average results. This is consistent with the preliminary results of the qualifying stage analysis and provides a basis for further comparison of winning and award-winning teams in individual subjects.

The calculations suggest that it is the physics task scores that cause the variation in team scores. To test this theory, we will compare the average subject scores of the winning and runner-up teams. Working hypothesis (H1): The average subject scores of the winning and runner-up teams differ. The results of the calculations are presented in *Table 4.*

Based on the results of the variance analysis at a significance level of 0,05, we can reject the null hypothesis of equality of average scores in chemistry, astronomy, biology and geography between the winning and award-winning teams. However, the average scores in physics differ by 95 % between the winning and award-winning teams.

The results of the analysis show that, for most subjects, there were no statistically significant differences between the winning and award-winning teams. In particular, the null hypothesis of equality of average scores is accepted for chemistry, astronomy, biology and geography at a significance level of 0,05. This indicates that the winning and award-winning teams demonstrate a comparable level of preparation in these subjects, and the results of the tournament are not decisive in distinguishing between these two groups.

In contrast, a statistically significant difference was found in physics between the average scores of the winning and award-winning teams. The average score of the winning teams in physics (3,997) is significantly higher than that of the award-winning teams (3,118), as confirmed by rejecting the null hypothesis at a given level of significance. Thus, physics is the only subject that differentiates statistically between winning and award-winning teams.

Table 4

Summary results of the variance analysis of the winning teams' and runner-up teams' scores by subject

Subjects	average score	df1	df2	F	F(0.05; df1; df2)	Conclusion on the acceptance/ rejection of the null hypothesis		
	Winning teams	Award-winning teams						
Physics	3,997	3,118	1	12	9,627	4,747	0,4451	reject
Chemistry	4,269	3,542	1	12	4,739	4,747	0,2831	accept
Astronomy	4,699	4,329	1	12	4,586	4,747	0,2765	accept
Biology	4,540	4,228	1	12	1,175	4,747	0,0892	accept
Geography	4,886	4,719	1	12	1,983	4,747	0,1418	accept

Source: own calculations.

These results are consistent with conclusions based on analyses of Tables 2 and 3, confirming the assumption that physics plays a decisive role in determining the final team ranking. While award-winning teams demonstrate a high level of training in most natural sciences, transitioning to the winner category primarily occurs due to a higher level of physical and mathematical competence.

Thus, the results of the variance analysis presented in Table 4 suggest that physics is a key "marker" subject that distinguishes between participants' high and highest achievements in the ONSD. This provides a basis for further analysis of the dynamics of physics scores over time, as well as the impact of the structure of physics tasks on team results.

Since we have shown that physics grades play a decisive role in determining the winners, we will present them in different categories in dynamics *(Fig. 1).*

Similar trends are evident in virtually all categories presented in the ratings dynamics of 2015–2017 and 2019–2021 (with the exception of changes in the ratings of the winning teams in 2020 and 2021). 2019 and 2020 saw higher scores than the previous year. Let us consider the factors that caused this.

Firstly, since 2019, participants have been asked to solve a calculation problem in addition to qualitative physics problems. *Figure 2* shows the corresponding distributions of average scores and the correlation between the average scores for qualitative and computational physics tasks among the main

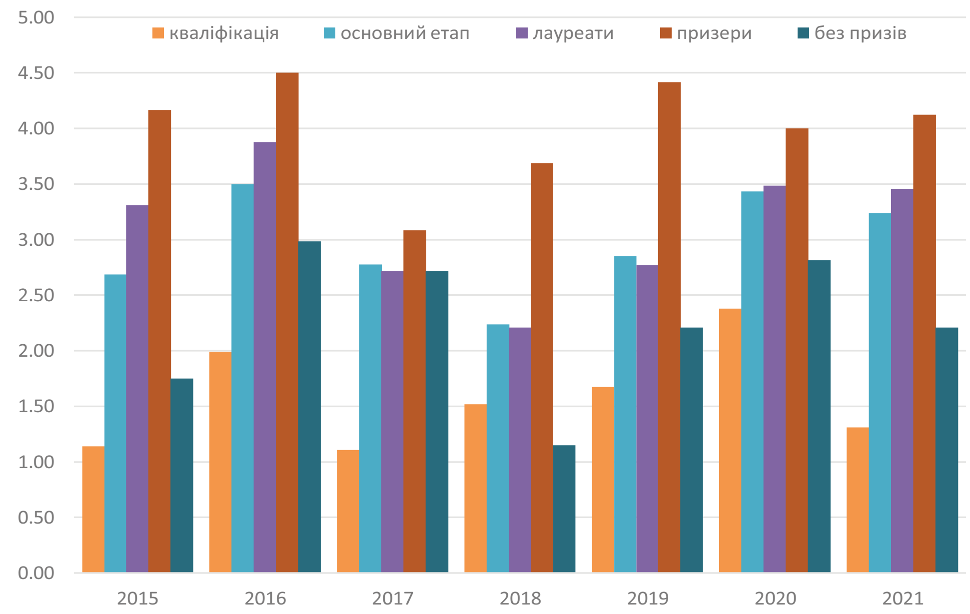

Fig. 1. Dynamics of average grades in physics. Source: own calculations

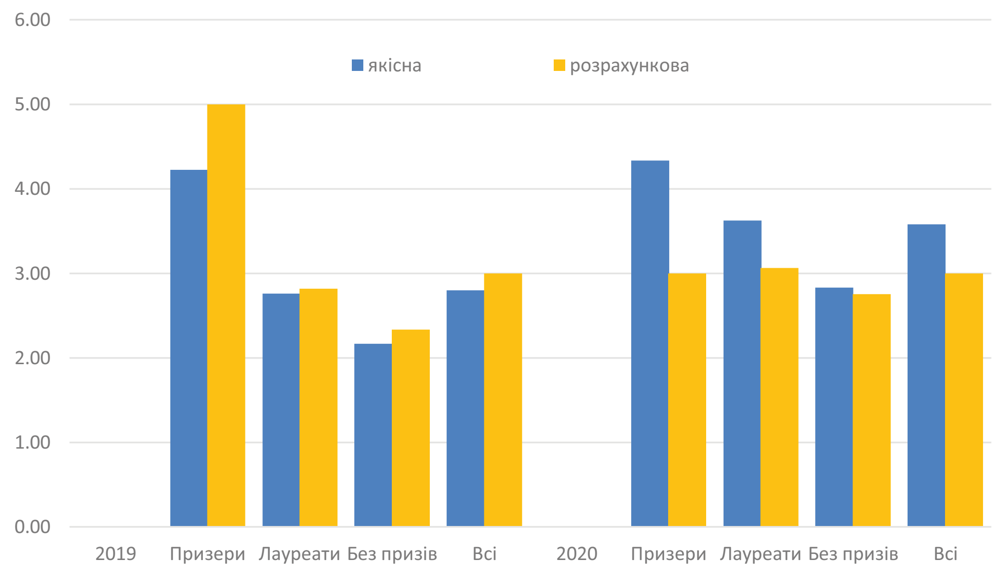

Fig. 2. Average scores for qualitative and calculation tasks broken down by participant category
Source: own calculations

categories of tournament participants (winning teams, award-winning teams and teams without awards) in 2019–2020. This was after the calculational component was introduced into the task structure.

The data show that the impact of task type on teams' results is unclear and depends on both the year of the tournament and the participants' level of preparation. In 2019, all categories of teams achieved higher average scores for computational tasks, which may indicate greater structure, clearer conditions, or better alignment with the algorithmic skills of participants developed through traditional education.

However, in 2020, there was a change in this trend, with average scores for qualitative tasks being higher or comparable to those for computational tasks. This dynamic may be due to changes in learning and training conditions for participants during the remote learning period, when conceptual thinking, the analysis of physical situations and working with visual information – characteristics of qualitative tasks – became more important.

Notably, for the winning teams, the difference between the scores for qualitative and computational tasks is less pronounced than for other categories. This suggests that they can work successfully with different types of physical tasks, regardless of the format. This is consistent with the previous conclusion that this group has a high and balanced level of physical and mathematical competencies.

For winning and non-winning teams, the difference between types of task is more noticeable, indicating that results are more sensitive to task format. In these groups, the type of task can significantly impact the final score and, consequently, the team's position in the rankings.

Thus, the data in *Figure 2* confirm that introducing calculation tasks does not necessarily improve results, and their effectiveness depends on the teams' level of preparation and the educational context. The results obtained emphasise the value of combining qualitative and calculation tasks in the tournament structure as a means of differentiating levels of academic achievement and developing various aspects of physical thinking.

Conclusions. The study confirms that the All-Ukrainian Internet Tournament in Natural Sciences ONSD is an effective informal science education tool. It combines elements of theoretical, practical, and mixed forms of scientific competition, and responds to the current challenges of STEM education development.

Statistical analysis of teams' participation in the tournament from 2015 to 2021 revealed stable and statistically significant differences in average scores depending on the subject area. The lowest average scores at both the qualification and main stages are consistently recorded for physics and chemistry tasks, suggesting their decisive influence on the team's overall result. Conversely, no statistically significant differences were found in the average scores for astronomy, biology and geography tasks in most cases, indicating a relatively consistent level of preparation among participants in these fields.

The results obtained allow us to conclude that the level of development of competencies in physics, mathematics, chemistry and natural sciences plays a key role in differentiating teams based on tournament results. This is particularly evident when comparing winning and award-winning teams: statistically significant differences were found only in physics, while average scores in other disciplines remained comparable. Thus, physics acts as a kind of "marker" of high-level interdisciplinary training and teams' ability to think scientifically in a comprehensive manner.

Another important outcome of the study is the identification of the impact of task structure on learning outcomes. From 2019 to 2021, the introduction of computational and research tasks in physics, biology, chemistry and astronomy contributed to an increase in the variability of results, creating conditions that allowed for a more thorough evaluation of participants' research, analytical and creative abilities. In the context of distance and blended learning caused by the pandemic and military events, video and research tasks focused on using available equipment or digital tools have demonstrated their viability and pedagogical relevance [10].

The statistical data obtained has important implications for STEM education policy. Firstly, they highlight the need to improve the quality of physics and chemistry teaching in general secondary education institutions, particularly by introducing research-oriented methodologies and using digital models and video demonstrations. Secondly, the results confirm the value of developing informal science education formats as a means of equalising educational opportunities for students, regardless of their educational institution's material resources.

Further research could involve an in-depth analysis of the 2022–2024 tournament results, considering changes in conditions, expanded research task ranges, and the long-term impact of ONSD participation on students' educational trajectories. Another area for future scientific research could be analysing the relationship between participating in the tournament and developing key research competencies, such as critical thinking, scientific communication and interdisciplinary knowledge integration.

References

1. European Olympiad of Experimental Science. (n.d.). *European Olympiad of Experimental Science: official website.* Retrieved from: https://www.eoes.science/.

2. STEM Olympiad. (n.d.). STEM *Olympiad: official website.* Retrieved from: https://stemolympiad.org/.

3. International Simulation Olympiad. (n.d.). *International Simulation Olympiad: official competition page.* Retrieved from: https://www.paanduvapplications.com/international-simulation-olympiad.

4. Davidson Institute of Science Education. (n.d.). *Cracking Programme.* Retrieved from: https://davidson.weizmann.ac.il/en/programs/cracking.

5. Genius Olympiad. (n.d.). *Genius Olympiad: international student competition.* Retrieved from: https://geniusolympiad.org/.

6. Destination Imagination. (n.d.). *Destination Imagination – Challenge Experience: educational project-based competitions.* Retrieved from: https://www.destinationimagination.org/challenge-experience/.

7. VPD – Holovna. (n.d.). VPD – Holovna [VPD – Home]. Retrieved from: https://vpd.stemua.science/.[in Ukrainian].

8. Junior Academy of Sciences of Ukraine. (n.d.). *Junior Academy of Sciences of Ukraine.* Retrieved from: http://man.gov.ua/en.

9. (2021). STEM laboratoriia MANLab. [STEM Laboratory MANLab]. Retrieved from: https://stemua.science/.[in Ukrainian].

10. Polikhun, N. I., Postova, K. H., & Slipukhina, I. A. (2020). Vyklyky dystantsiinoho navchannia [Challenges of distance learning]. *Osvita ta rozvytok obdaro-vanoi osobystosti – Education and Development of Gifted Personality, 3*(78), 63-69. DOI: https://doi.org/10.32405/2309-3935-2020-3(78)-63-69. [in Ukrainian].

Чернецький Ігор Станіславович, кандидат педагогічних наук, завідувач відділу створення навчально-тематичних систем знань, Національний центр «Мала академія наук України», м. Київ, Україна

Вільчинська Оксана Миколаївна, кандидатка економічних наук, доцентка, доцентка кафедри статистики економічного факультету, Львівський національний університет імені Івана Франка, м. Львів, Україна

Сліпухіна Ірина Андріївна, докторка педагогічних наук, професорка, головна наукова співробітниця, Національний центр «Мала академія наук України»; Інститут обдарованої дитини НАПН України, м. Київ, Україна

СТАТИСТИЧНІ ХАРАКТЕРИСТИКИ ВСЕУКРАЇНСЬКОГО ІНТЕРНЕТ-ТУРНІРУ З ПРИРОДНИЧИХ НАУК «ВІДКРИТА ПРИРОДНИЧА ДЕМОНСТРАЦІЯ»

Анотація.

У цій статті представлено результати дослідження Всеукраїнського інтернет-турніру з природничих наук «Відкрита природнича демонстрація», у якому розглядається його використання як інструменту неформальної наукової освіти та розвитку обдарованих учнів. Було проаналізовано результати участі команд у турнірі в період з 2015 р. до 2021 р. із метою визначення предметних чинників, що впливають на варіативність навчальних досягнень учасників і роль турнірних заходів у розвитку ключових дослідницьких і STEM-компетентностей. Методологія дослідження ґрунтується на методах описової статистики, аналізу дисперсії та порівняльного аналізу результатів команд у різних категоріях (призери, лауреати та учасники без нагород). Під час дослідження було виявлено статистично значущі відмінності в середніх балах залежно від предметної області. З'ясовано, що завдання з фізики та хімії мають найбільший вплив на кінцеві результати команд, тоді як результати з астрономії, біології та географії в більшості випадків є відносно стабільними. Дослідження показує, що рівень розвитку компетенцій з фізики та математики є ключовим фактором диференціації команд за результатами турнірів, особливо в процесі розмежування команд-призерів та команд-лауреатів. Продемонстровано освітній потенціал використання відео-, обчислювальних і дослідницьких завдань для розвитку критичного мислення, міждисциплінарної інтеграції знань і культури досліджень серед учнів у дистанційному та змішаному навчанні. Отримані результати можуть бути використані для вдосконалення змісту неформальної наукової освіти, розробки освітніх конкурсів для обдарованої молоді та підвищення якості викладання природничих наук у закладах загальної середньої освіти.

Ключові слова: *наукова освіта; неформальна освіта; обдаровані учні; інтернет-турнір; природничі дисципліни; STEM-освіта; дослідницька діяльність; відеозадачі; міждисциплінарна інтеграція.*

Прийнято 24 листопада 2025 року. Затверджено 12 грудня 2025 року