International physics competitions for secondary school students – What can they learn?

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QVO NON ASCENDAM?

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Abstract

Extracurricular activities for physics students in upper secondary schools could, for instance, take the form of participation in national or international physics competitions. One such event is the International Young Physicists' Tournament (IYPT) which takes place once every year in different countries. Another one, better known, is the International Physics Olympiad (IPhO). This competition is on an individual basis whereas IYPT involves a team of five young competitors. Yet another annual event is the Polish First Step to Nobel Prize in Physics (FS). The organizations of these three competitions will be described and examples will be given of problems presented for and by those participating. IYPT and FS both require some research activities as a preparation for the presentations of solutions. Thus, the skills which will be developed in such activities might be different from and complementary to the ones which are normally emphasized in ordinary school curricula.

Keywords: International competitions, Physics tournaments, Assessment of Physics.

Resumen

Actividades extracurriculares para los estudiantes de física en las escuelas secundarias podrían, por ejemplo, tomar la forma de participación en competiciones nacionales o internacionales de física. Uno de estos eventos es el Torneo Internacional de Jóvenes Físicos (IYPT), que se lleva a cabo una vez al año en diferentes países. Otro, más conocido, es la Olimpiada Internacional de Física (IPhO). Este concurso es a nivel individual, mientras que IYPT involucra a un equipo de cinco jóvenes competidores. Otro evento anual es el paso de Polonia Primer Premio Nobel de Física (EF). Las organizaciones de estos tres concursos se describen y se darán ejemplos de los problemas presentados por y para los participantes. IYPT FS y ambos requieren algunas actividades de investigación como una preparación para la presentación de soluciones. Por lo tanto, las habilidades que se desarrollan en estas actividades pueden ser diferentes y complementarias de las que normalmente se hizo hincapié en los programas escolares ordinarios.

Palabras clave: Competencias internacionales, Torneos de Física, evaluación en Física.

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I. INTRODUCTION

Since several decades physics competitions of different kinds have been organized all over the world. In most cases the participating students come from upper secondary schools; very often the participants are pupils in the last grade before entering university. The best known is the International Physics Olympiad (IPhO), an international individual competition which unlike the Olympic Games is organized every year in different countries. Other events are regional or national, sometimes with invitations for participation by students from neighbouring countries. Here two more of the international physics competitions will be described, namely the First Step to Nobel Prize in Physics (FS) and the International Young Physicists' Tournament (IYPT).

It is clear that the competitive element of these events can spur young people to study the discipline of physics more deeply and make them proceed to the truly fundamental experimental side. The fact that participation involves meeting young people from other countries can also be a source of inspiration. In addition, such an event gives a chance to talk to experienced physicists like university researchers, perhaps during a whole week of being together during a competition. A common problem to the various alternatives is the fact that only a small number of young persons can participate. However, arranging national qualification events for the selection of the best group will of course spread the knowledge and benefits of the competitions. It is interesting, but not surprising, that all three of the major physics competitions, those chosen for discussion here originate from East or Central European countries. One has the feeling that ranking people was in many political systems a very important issue with an impact on career and salaries, whereas in other systems such ranking was considered less important, maybe even not desirable, for decisions of the status of citizens.

In this paper an attempt will be made to compare the aims and achievements of the three competitions mentioned above, IPhO, IYPT and FS, and to see in which way the activities involved could help raise the interest of young people for the discipline.

II. THE INTERNATIONAL PHYSICS OLYMPIAD

A. Brief history

As mentioned in the introduction the International Physics Olympiad (IPhO) is the oldest of the three competitions to be discussed. It is described in Ref. [1] and on the official web site [2]. The quotes given below are all from the history reported in [1]. The first event happened in 1967, on the initiative of Czeslaw Scislowski from Poland, and was organized in the Polish capital, Warsaw. In addition to Scislowski two other European physicists were also involved at the start, namely Rotislav Kostial from former Czechoslovakia and Rudolf Konfalvi from Hungary. The three initiators had been inspired by the success of the International Mathematics Olympiad which had been running annually since 1959. In the two following years the event was actually arranged in Hungary in 1968 and in former Czechoslovakia in 1969.

After a few years of tentative organization the more definitive structure of IphO was decided in 1971 when the competition was held in Sofia, Bulgaria. Since that year five pupils and two supervisors are admitted from each participating country. In 1973, for the first time, a non-European country, Cuba, and a country from western Europe, namely France, participated. The growth in the number of countries has been spectacular: from less than 10 in the 1960's the most recent statistical tables now show over 90 countries listed.

B. Structure of the competition

The competition lasts for two days. One day is devoted to theoretical problems (three problems involving at least four areas of physics taught in secondary schools). Another day is devoted to experimental problems (one or two problems). These two days are separated by at least one day of rest. On both occasions the time allotted for solving the problems is five hours. The problems are selected by the local organizers and are strictly regulated by the existence of The Syllabus, an extensive list of allowed subfields of physics to be treated, eleven in all. As an example for the theoretical part it might be mentioned that under the heading Quantum Physics two areas are listed: a) Photoelectric effect, energy and impulse of the photon, and b) De Broglie wavelength, Heisenberg's uncertainty principle. As a comment to a) it is stated that "Einstein's formula is required".

Each team consists of students from general or technical secondary schools (not colleges or universities). No more than five pupils can make up a team and they are accompanied by two supervisors. Together the latter form the International Board which is the highest authority of the IPhO. A technical problem arises with the experimental part of the competition since a very large number of stations is required by the organizers. All of these must be equipped in a way which gives the same chance to each participant.

An interesting feature of the competition is that all problems are given in the national languages of the participants. As is said in the report quoted above: "IPhO is a competition in physics, not in foreign languages". It might be thought that the translation of the wording of a problem could cause difficulties in checking whether the new wording exactly corresponds to the intention of the authors of problems; a similar dilemma could of course appear in grading the answers when they are given in so many different languages. However, the grading is made in unison between the organizers and the supervisors (teachers) accompanying the participants "until an agreed mark has been reached". It should be mentioned that since some years all team supervisors are required to have working knowledge of English. There is no collective grading or ranking of teams based on the country of origin, IPhO is a strictly individual competition. "Non-existence of team classification is important. We do not wish to introduce rivalry between nations".

C. Significance of the IPhO

Naturally the preparation periods imply deepened studies, very useful at least for those selected as participants. However, for the outcome of the competition, especially with shorter preparation times, there must be some element of luck for the training to be suitable.

Speaking of the preparation for participating pupils it looks very different in different countries, so different that it is considered somewhat problematic. The time assigned varies between a few days, or even nothing, up to months. As formulated in [1]: "…too intensive training may deform the results. After a long and intensive training even an elephant may dance to the tune of a piper". However, in most countries the time set aside for training is more reasonable, of the order of 5 – 10 days. Considering its long history it is not surprising that the statistics available for IPhO can be very interesting to study. Although some countries, like China and Iran, reporting very long preparation periods for the students, also show very good performance, there are other examples contradicting this correlation. The APS News [3] gives a very nice account of the 9-day preparation and selection of the US team to the 2006 event in Singapore. The training took place at the University of Maryland and was organized by the American Association of Physics Teachers.

Like in all international encounters the possibilities of useful contacts, also in the future, between the participants, teachers as well as pupils, are stressed in discussions on the significance of an IPhO event. The teachers could exchange ideas about methodology in physics education, the content of text books etc. For the pupils, especially if they enter university, there are possibilities of renewed encounters in the future. University student exchanges are becoming more and more frequent, all over the world, and previous contacts with contemporaries might be very important for the choice of schools to visit.

III. THE INTERNATIONAL YOUNG PHYSICISTS' TOURNAMENT (IYPT)

A. History and administration

In this section a team competition called the International Young Physicists' Tournament (IYPT) will be described, in particular with respect to the skills one hopes to develop among participating students. The history of IYPT dates back to 1988 but in the beginning the event was always organized inside the Soviet Union or, from 1992, in Russia. However, already from the year 1979 there was a precursor organized at Moscow State University for secondary school students from the Moscow region. In 1994, for the first time, it was arranged in a different country, namely The Netherlands. Up until now seventeen countries have organized IYPT with a slightly fluctuating number of countries participating. In 2004, for the 17th IYPT, Brisbane, Australia, was the host for 26 teams from 24 countries, representing six continents; in 2009 China, and in 2010 Austria hosted the IYPT event. The 24th event was organized in 2011 by Iran and 21 countries took part.

The details of the competition structure are strictly prescribed in Regulations, whereas the organization itself is ruled by Statutes, adopted in June 2004. The governing body is an International Organizing Committee (IOC) which meets at least once annually, during an IYPT event. The event itself is arranged by a Local Organizing Committee (LOC). Between IOC meetings an Executive Committee handles the issues as decided by IOC. It consists of eight members: President, Secretary General, Treasurer, two members elected by the IOC and the three LOC chairpersons from "last year, this year and next year". The fiscal year of IYPT runs from November 1 to October 31.

B. IYPT structure

The structure of the competition has been developed through the years from the start, but the changes introduced have normally been slight. In each of the five qualifying rounds, called Physics Fights, three, or sometimes four, teams meet and present their solutions to one each of the 17 problems on the list. A team consists of five members, representing one country. However, until the year 2007 the host country could have two teams participating. As a remnant from history the Russian language was allowed in the discussion for a few years; nowadays everything is conducted in the English language.

Which problem a certain team has to tackle is decided by a so called challenge from one of the other teams present in the qualifying round. There are three roles possible in a round: Reporter, opponent and reviewer. The opponent challenges the reporter for one of the problems. The reporter can refuse or accept the challenge, but after a total of three refusals during the five rounds the grading of the jury will be lowered. After the report of the solution the opponent will scrutinize the solution and point out merits as well as possible weaknesses. The reviewer comments both the solution of the reporter and the remarks of the opponent. All items on the agenda are strictly timed. The report, for instance, can take no more than 12 minutes, whereas the opposition and the following discussion with the reporting team are allowed a maximum of 15 minutes.

After this first stage of a particular qualifying round the roles are changed, and at the end of a full round all three teams have had each of the three roles. If four teams are present the members of the fourth are called observers; they remain passive during each stage of the round. Also this role is adopted by each of the four teams in turn.

The performance of the teams is graded by an international jury, composed of normally 5 to 8 members who are either independent or connected to one of the teams not participating in that particular round. If possible all jury members come from different countries and none of them comes from the same country as a participating team. The grading of the jury is recorded and forms the basis for a decision, after the five qualifying rounds, to select the best three teams who compete in the final round. The rules are different in the final in the sense that the three teams choose themselves which problem they want to handle. The choice is made according to the ranking after the first five rounds, the team with the highest ranking chooses first, etc.

C. IYPT problems, selection and examples

The 17 problems to be solved by participating teams are nowadays published on the Internet typically ten months before the competition takes place. They are finally decided by IOC on suggestions from an international group of physicists, consisting of both school teachers and researchers from various institutions, mostly universities. The IOC normally has well over 100 problems to choose from. Care is taken to spread the problems over as many subfields of physics as possible. Additional criteria involve the need for problems which require some experimental research and which are by their nature "open", *i.e.*, they should not have a unique solution but rather be possible to handle from different aspects and thus to give alternative solutions. Physics subfields which are quite frequent among the selected problems are mechanics, electricity/magnetism and optics. In these cases it is relatively easy for the students to find equipment in their schools, to construct models and develop strategies for discussing their solutions.

However, it has been shown difficult to list problems from certain areas like "modern" physics. Partly this is due to the assumption that many school curricula do not include this subfield, partly also to restrictions in handling radioactive substances, for instance. In general it could be added that the selected problems often favour schools with modern laboratory equipment. However, in judging the presented solutions the jury can take into account the ingenuity and creativity of the participants and thus compensate for the lack of equipment.

Some examples of problems will be given below, in order to show the character of typical IYPT problems. In 2003 IYPT was organized in Uppsala, Sweden. The winning German team had chosen the following problem: *Heat engine.*

Construct a heat engine from a U-tube partially filled with water (or another liquid), where one arm of the tube is connected to a heated gas reservoir by a length of tubing, and the other arm is left open. Subsequently bringing the liquid out of equilibrium may cause it to oscillate. On what does the frequency of the oscillation depend? Determine the pV diagram of the working gas.

The second problem was given in Brisbane in 2004: *Didgeridoo.*

The 'didgeridoo' is a simple wind instrument traditionally made by the Australian aborigines from a hollowed-out log. It is, however, a remarkable instrument because of the wide variety of timbres that it produces. Investigate the nature of the sounds that can be produced and how they are formed.

This problem was chosen by the Polish team in the final and the solution presented live performances as well as theoretical descriptions of how the sound was produced. The solution of this problem made the Polish team winners.

The third was chosen by the winning Croatian team in Bratislava in 2006 and had the following wording: *Electrostatics.*

Propose and make a device for measuring the charge density on a plastic ruler after it has been rubbed with a cloth.

The city of Tehran in Iran hosted the 24th IYPT in 2011. In that event the following problem appeared – it had to do with a legend concerning Vikings: *Vikings.*

According to a legend, Vikings were able to navigate in an ocean even during overcast (dull) weather using tourmaline crystals. Study how it is possible to navigate using a polarizing material. What is the accuracy of the method?

D. What skills are developed?

For participants in the IYPT competition it is evident that certain skills are needed for success. Some of these are essential also for success later in life, if a student chooses to continue to a career in physics research or in teaching.

In the preparation for the competition some experimental research as well as a study of the theoretical basis for a solution to the problem are needed. This work would normally be done in a team, sometimes inside the team that appears in the competition. In addition, search in the literature is normally performed, and the participants have the liberty to quote suggestions from elsewhere, also from teachers or professional researchers. Already it is clear that to be prepared for the event itself the following skills have to be developed:

Experimental research,
Theoretical study, Correct references to other results quoted, and Team work.

The reports are given in English and the time assigned is quite limited. For the vast majority of teams English is a foreign language; some years back no team in fact had English as their mother tongue. It is thus essential to learn to present a solution in a clear, convincing and logical way and to be disciplined regarding the time to be used. In addition, the use of modern visual means of presenting a report becomes increasingly important for the outcome. The corresponding skills would be: *To present as clearly as possible the solution suggested, using modern means of communication, and to plan the report within the time given.*

In the discussion periods, between opponent and reporter as well as when the reviewer makes comments, great emphasis has traditionally been put on the way possible criticism is formulated. Unnecessarily aggressive behaviour will be punished by the jury. Remarks like "Obviously you have not understood the physics behind your reported solution" do not open for an efficient discussion and must be excluded. Adding the fact that an IYPT event, when hundreds of young students from all over the world meet and associate for a week, calls for some behavioural attitudes, one might add to the list the need for and development of *Social skills in a broad sense.*

E. The selection of national teams

Just as was the case for IPhO different countries have adopted quite different strategies for selecting their national teams. Quite a few organize their own national qualifying competitions in order to find the best team for representing their country. In some cases the selected students are also invited to prepare for their performance in IYPT at a university. Other countries depend on one or a few enthusiastic physics teachers who trim and encourage pupils from their own classes.

The school curricula in different countries also differ substantially, making it more or less difficult to fit in the rather extensive preparation needed for students of the final year in upper secondary schools.

It is clear that if only the resulting ranking would be important for participating teams such different preparation possibilities could appear unjust. However, like in most other instances it is only fair that those who have the best preparation also reach the best ranking. In addition there are certainly many other positive features of participating which compensate for a less successful ranking.

Since in many countries girl students show less interest in physics than boys it is encouraging that a considerable number of girls do participate in IYPT. It is possible that the cross-disciplinary nature of some of the problems is a contributing cause.

F. The future of IYPT

In contrast to the case of the International Physics Olympiad the list of candidates for arranging future IYPT events can be very short. In fact, for 2011 Iran was the only one. For 2012 Germany has offered to be the host and in

2013 it might be the turn of Chinese Taipei. For IPhO the list runs up to the year 2023 when Iran will be the host, just as it was in 2007 [2].

An international organization, the World Federation of Physics Competitions (WFPC) was recently set up. It held its fourth Congress in Baske Ostarije, Croatia, July 25 to 29, 2010. The importance of events like the three physics competitions treated in this paper is often discussed in their journal Physics Competitions by experienced teachers who have also been organizers of different events. In particular the paper by Z. Rajkovits and L. Markovich [4] makes interesting comments on IYPT.

IV. FIRST STEP TO NOBEL PRIZE IN PHYSICS

A. History and aims

The history of the "First Step" competition begins in the school year 1991/92 when it was arranged as a national competition in Poland. The initiator was Waldemar Gorzkowski who describes in Ref. [1] how the idea emanated from the observation that "some of the high school pupils tried to carry out physical research by themselves – at schools, in some laboratories and even at home". The pupils in question were among those being trained in Warsaw for their participation in the IPhO, or those involved in Research Workshops organized by the Institute of Physics, Polish Academy of Sciences. Already in the second year, 1992/93, the competition turned international, under the present name.

This competition has a rather different character than the two described above. Pupils all over the world can participate, with the condition that their school "cannot be considered as a university college" and that they are under 20 years of age on March 31 during the corresponding school year. That date also constitutes the deadline for submitting the papers to be considered for evaluation by the examiners. As stated in the First Step rules the papers should describe a piece of research carried out by the participant on a physics topic decided by himself/herself. In addition the reports should "contain new, original and interesting results…either in theory or in experiment or in constructing devices (or instruments)…. presented in an appropriate way, characteristic for research papers". The final condition might seem quite stringent: "The papers should be ready for publication without any changes or after minor changes of editorial character only". It is hard to believe that the organizers, in speaking of publication, think of ordinary research journals where the editors work with a set of referees judging incoming material. On the other hand, this very strict rule only applies if the participant would be the candidate of an award. For an "honourable mention" it is stated that "the paper is not ready for publication without more or less important changes which exceed editorial character only".

As stated in Ref. [5] the main aims are the following: Promotion of scientific interests among young people;

Selection of outstanding pupils (this point is especially important in case of pupils from countries or regions in which access to science is difficult) and their promotion (very often our winners enter better universities and receive appropriate financial help from the local authorities);

Stimulation of the schools, parents, local educational centres, etc. For greater activity in work with pupils interested in research (we know that in some countries, some regions and even in some schools a preliminary local selection is organized, sometime such selections involve great numbers of participants);

Establishing friendly relations between young physicists (recently all the winners are invited to the Institute in the same time, they are accommodated in the same place, they cooperate with each other, etc.).

Some of the explanatory texts in the above statements are interesting also in the sense that they shed light on the effect of successful participation in the other two competitions discussed in this paper. Firstly it is believed that the winners will experience a better treatment on the return to their home countries, amounting to having access to "better universities" and "appropriate financial help". Although this is probably true for some countries there are indeed other countries where access is judged after evaluation of success in the regular school system or even completely free after finished upper secondary school. Secondly it is observed that some countries organize national qualification rounds, involving many more pupils than those selected for participation. This observation is important in the sense that the impact of international physics competitions otherwise would seem rather meagre, judging from the proportion of pupils actually influenced by the stimulus that an international competition can offer. Thirdly, and this is an increasingly important point today, the text emphasizes the great value in international encounters of young people sharing similar interests. As indicated above these three points, at least in some countries, are probably valid for all three competitions discussed here.

B. Examples of topics presented in research papers

The complete list of research papers submitted to the First Step competition is now very long. In 2005/06, for instance, during the 14th year of the competition, no less than 99 papers were submitted; four of these were awarded by the organization committee and the authors were invited to stay for a month in a Polish research institute. Since the beginning over 2000 papers have been received from young researchers in a total of 76 different countries.

The topics chosen by the four competitors winning awards during the 2005/06 event were the following: Mechanics of superbouncing (participant from Bulgaria), Analysis of movement of ink in water – an experimental study (Iran), Measuring the temperature dependence of the air thermal conductivity under constant pressure (Russia), and Study of extrasolar planet formation by observing eclipsing binaries (Singapore). Even though problems of, for instance, mechanics and electromagnetism are often chosen, it is quite amazing that there are also a number of contributions from fields like astronomy, astrophysics, cosmology, and subatomic physics. In Ref. [5] useful statistics show the extent of the interest in FS worldwide. It is clear that some countries are more often than others represented in the group of winners. As an example it may be mentioned that during 2001-2006 years six countries, namely Bulgaria, Indonesia, Iran, Latvia, Russia and Singapore had three or more winners each.

V. CONCLUDING REMARKS

It is worth noting that the organizers of the First Step competition have the following phrase [5] as their motto to guide the young participants: *"Physics should not be developed for physics itself - physics should be related to our life and serve the people"*. This recommendation is of course not always easy to follow. Part of the time when physics is studied must be devoted to general laws which do not seem to have much to do with "our life" or would help to "serve the people". However, looking more carefully into the significance of such a statement, one realizes that the motto is similar to the advice given to physics teachers in general: In order to increase the interest in the discipline among young people one should try to include everyday issues, phenomena that the pupils can relate to in one way or another. Ideally the participation in international physics competitions develops skills which were enumerated above in discussing IYPT, skills which are quite useful in our complex societies where many problems have to be solved using methods which are based on deep knowledge of physics as well as of other scientific disciplines. Maybe, in the future, one might hope to see competitions where the selected problems are drawn from cross-disciplinary areas. In university research some of the old frontiers between different subjects are becoming blurred. The 2010 Nobel prizes in physics and chemistry are good examples of how even such distinguished scientific judges as the Nobel committees have difficulties in completely distinguishing one branch from the other!.

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