Selection and training of students in Hungary

Historical background

Science competitions have a long tradition in Hungary: the first maths competition was organized in 1894, the first physics competition in 1916. The "Mathematical and Physical Journal for Secondary Schools" (KöMaL) is published since 1894, too. Science education in Hungarian secondary schools was famous between the World Wars. Theodore von Kármán, George de Hevesy (Nobel Prize in Chemistry 1943), Eugen Wigner (Nobel Prize in Physics 1963), John von Neumann, Leo Szilárd, Edward Teller were pupils of high schools in the same district of Budapest before their international scientific carrier. The strong maths and science education continued after 1945, and national competitions have been organized already in all of the subjects. In the 60's Hungary was the founder (and several times the organizer) of international olympiads (IMO, IPhO, IChO).

In Hungarian secondary schools science is taught in *separated subjects* (physics, chemistry, biology, geography), the curriculum is more *theoretical* and the exams – similarly to the competitions – are *individual*. Therefore it was a great challenge for Hungary to take part in EUSO – first time in 2009 –, where biology, chemistry and physics are *connected*, the problems are mostly *experimental* and pupils have to work *in teams*.

Selection of EUSO teams

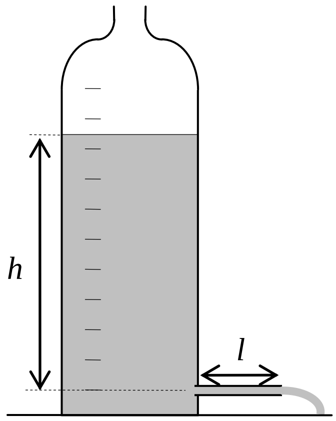
According to the Hungarian school and competition system mentioned above the selection and preparation of team "experts" for physics, chemistry and biology take place separately. In every May there are the final rounds of national competitions in biology, chemistry and physics for 9th and 10th grade pupils. As the next school year starts in September the best 30-40 competitors in each subject are invited to the EUSO preparation organized by the corresponding mentors. The selections of two biologists and chemists for the two Hungarian teams take place in Szeged (Radnóti Miklós Experimental High School) while physicists are prepared and selected in Budapest (Budapest University of Technology and Economics). Since I am responsible for physics it will be discussed in details but the selection and preparation of the other two subjects are to be progressed similarly.

The national competition in physics for 9th and 10th grade pupils is the "Sándor Mikola National Physics Competition" (Sándor Mikola was the physics teacher of Eugene Wigner and John von Neumann.) It is organized in three rounds: the first two rounds are only theoretical, in the final round there are both theoretical and experimental problems. This competition has a relatively bright base: in the first round about 3500 students participate. The best 50 pupils of each grade take part in the final and from them about the best 20 of each grade (who are not too old for EUSO participation) are invited for the preparation and pre-selection.

Experimental physics problems

In the first months they have to solve some experimental problems (which need no difficult apparatus) at home. They submit their results and reports which will be marked. The best five or six of them are invited to the final selection competition where the two team members are to be selected. During this two days long competition further experimental problems are solved with a little bit more sophisticated devices they are used at home before.

As example I present one of the experimental problems given for homework:



1. Prepare your measuring device as shown in the Figure.
   Make a small hole on the side of a plastic bottle (2-3 mm in diameter) and glue a straw in the hole. Prolong the straw with another one, so you will have got an approximately l = 0.5 m long pipe. Support it to be horizontal.
   Measure the inside diameter d of the pipe.

2. Calibrate the bottle.
   Close the pipe and fill water by a measuring cup into the bottle. Fill 100 ml into the bottle and mark the level. Repeat this process until the bottle is full.
   Measure the medium height h between two marks and calculate the hydrostatic pressures p for each height.

3. Measure the speed v of water as a function of the hydrostatic pressure p.
   Fill the bottle and let the water flow. Measure and tabulate the time t necessary for going out each 100 ml of water (between two marks).
   From these times determine and tabulate the velocity v of water as a function of the hydrostatic pressure p.

4. Repeat these measurements for different pipe lengths.
   For example l = 40 cm, 30 cm, 25 cm, 20 cm, 15 cm, 10 cm, 7 cm, 5 cm, 3 cm, 1 cm and 0.5 cm.

5. Plot your results.
   Plot the flow velocity v versus the hydrostatic pressure p. Display the data measured at different lengths by different colors on the same graph.
   Plot the flow velocity v versus the length l of the pipe. Display the data measured at different pressures by different colors on the same graph.

6. Determine the viscosity of water.
   The flow of water in long pipes is primarily determined by internal friction (viscosity). According to Poiseuille's law, the average velocity can be calculated with the following formula (in laminar flow):

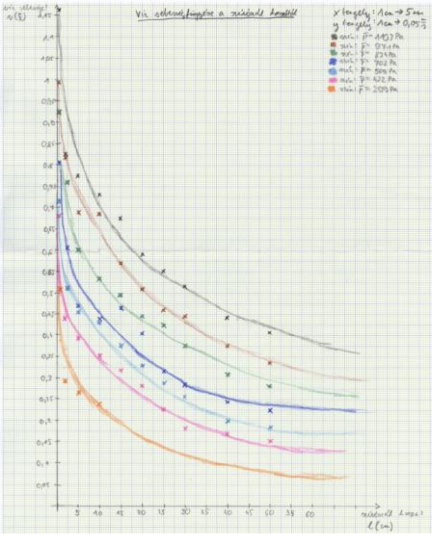
   $$v = \frac{r^2}{8\eta l} p \ ,$$

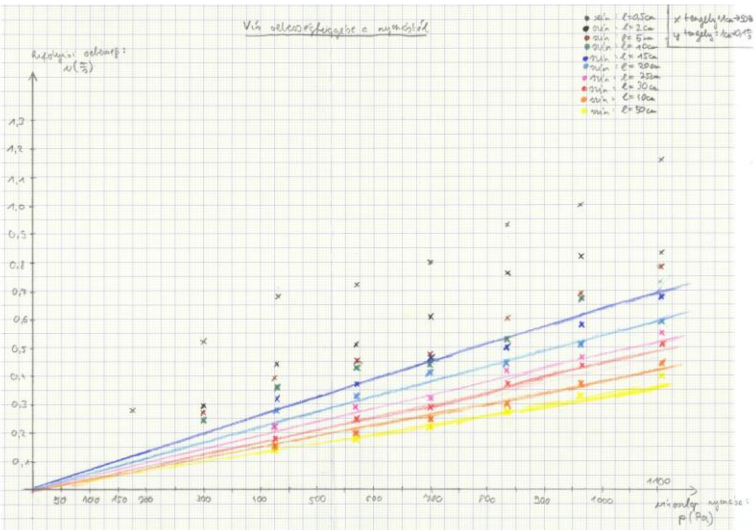
   where v is the velocity of water, r is the radius of the pipe, η is the viscosity of water, l is the length of the pipe and p is the pressure difference between the ends of the pipe.
   Use the graph v versus p and fit straight lines on the data measured at longer pipes. From the slope determine the viscosity of water.

7. <u>Note the narrowing of the jet.</u>
   The flow of water during a very short pipe (or a hole) is determined by the acceleration of water. According to the Bernoulli's law:
   $v = \sqrt{2gh}$,
   where v is the velocity of water, h is the height of the water column and g is the gravitational acceleration.
   However, the water jet becomes narrower then the hole, and thus its diameter will be smaller then the diameter of the pipe (or the hole).
   Estimate this narrowing from your results measured at the shortest pipe.
   Observe the narrowing of the jet and compare your observation with your estimation.

8. <u>Estimate the surface tension of water.</u>
   The flow will be stopped already at finite hydrostatic pressure and you can see a small water drop at the end of the pipe. In this case the surface tension of water causes an internal pressure in the drop and this pressure holds equilibrium with the hydrostatic pressure.
   The internal pressure of the drop:
   $$p_i = \frac{2\alpha}{r},$$
   where p_i is the internal pressure, α is the surface tension and r is the radius of the pipe (and the drop).
   Estimate the surface tension of water based on your measurement.

And let see two graphs from a report:





Training of EUSO teams and results

After all of the selection competitions every team members and mentors have a meeting in Szeged or in Budapest for one or two days where the final teams are formed and members can get to know each other. In addition some data analysis techniques, as graph plotting, line fitting or error estimation are explained, and the students can make some simple measurements by devices commonly used (e.g. multimeters) together. They can study the text of former EUSO problems, but there is no possibility to perform complex measurements and really solve the problems. Here is a potential for improvement: the teams should make some experimental work together and learn more how to cooperate during the competition.

The EUSO results of Hungary – compared to the size and the possibilities of the country – are *till* 2015 very good: at least one gold medal in each year (two times two gold medals) and absolute winner in 2011 and 2014. The main reasons of these results, in addition to the long tradition of science competitions, are *a few* very good secondary schools with very good teachers. Unfortunately the number of these really good schools is really low (under ten) and team members have to be chosen from smaller groups of interested student each year. There is no hope in the near future that this tendency will be reversed. So that our future success is not guaranteed at all. But we will try our best…

Péter Vankó