# RESEARCH OF NEW FORMS OF COMPETITIONS IN FOSTERING THE CREATIVITY OF YOUTH

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## Abstract

*People working in basic science are rightly concerned about a potential decline in the number of physics students. At the Faculty of Science, Palacky University in Olomouc, Czech Republic, we have prepared a project entitled „Research of new forms of competitions in fostering the creativity of the youth aimed at motivating them to study science, especially physics, mathematics and chemistry". Some of the research activities will be discussed in this paper, namely the competitions Fermi Questions and The Young Inventor. The basic question of our research is the efficiency of this activities for the motivation of students to study physics and techniques. It will be shown that only a small number of students were interested in these competitions. The Fermi Questions competition was organized as an international one in cooperation with secondary and high school teachers in Germany in 2008. The results are the same as in the Czech Republic. The competition The Young Inventor was successful – the presented papers and the convention had shown a good quality of students´ knowledge, some of them cooperate with industrial enterprises and intend to study physics.*
**Key words:** *competition, Fermi questions, young inventor, motivation, physics.*

## Introduction

High school students are not interested in science and technics. The number of our physics students (applied physics, biophysics, optics or prospective physics teachers) is falling rapidly. Now we can see a shortage of high school physics teachers at our schools. At the Department of Experimental physics - didactic physics we started a lot of activities to motivate secondary and high school students – research activities, competitions, trade fairs of experiments, open doors etc. The recruitment of students will start with more activity and creativity of kids. We will show them the importance of physics and techniques, we are trying to develop a closer secondary and high school-university partnership and provide professional development opportunities.

One of the most important fields for the recruitment of new generations to science is the secondary school. This is the age of self-discovery, when adolescents explore their capabilities and limits, and seek a place in society. Science and research offer a unique opportunity for adolescents to quench their thirst for answers and explore their intellectual strengths and capabilities.

Skills required in science are the ability to estimate an answer to a problem and to determine whether an answer is reasonable or not. These skills are not "intuitive", and students require constant practice to develop and hone them. One of the most entertaining ways of developing estimation and reasoning skills is by means of the "Fermi Question". To obtain answers to Fermi questions, students are first required to formulate a solution strategy then estimate all the relevant quantities before computing an "answer." Because such an answer is only approximate, students soon come to appreciate that it is the method rather than the answer itself that is most important. A bonus to this approach is that these skills we can apply to a variety of problems in life, and not only in the science classroom. This paper reports on a research aiming to investigate the possible potential of using Fermi questions to introduce logical thinking as one of the most important competences. Dirks and Edge (1983) pointed out that things typically required when solving Fermi problems is sufficient understanding of the problem to decide what data might be useful in solving it, an ability to estimate relevant physical quantities, and some specific scientific knowledge (p.602).

## Methodology of Research

The aim of our research is the analysis of solutions that sent us the participants in the Fermi questions competitions in 2006 and 2007. According to the papers of the participants of these two competitions we are trying to describe and analyse the process of solving the Fermi questions. The structure of the solution is given and has several steps:

> 1. Understand the problem (reading of the tasks), 2. Analyse the problem – put down a plan, 3. Ask many more questions, 4. Answer the questions, 5. Estimate the result, 6. Calculate, 7. Look back to review the result.

For our purpose, we developed a judging process as described in the next part of the paper. During the Finals at the Department of Experimental Physics we tested the ability of the team to discusse about the problem in the group. This was one of the key reasons to be successful in the competition.

Students can use their physical intuition and their own experiences. Analysing the papers we can see if the student makes a guess based on a misconception. The discussion and reviewing the results is good way to change this misconception. Many Fermi questions are characterized by the absence of numerical data. Students have to estimate the quantities. They improve the skills in making realistis estimate.

## Fermi Questions

A Fermi Problem, named after the Italian physicist Enrico Fermi, is a problem in which realistic estimation and order-of-magnitude calculation are essential. The idea of a Fermi Problem is to think about what assumptions we make, how to make them as realistic as possible.

Fermi was popular for asking his students outrageous and seemingly impossible questions, and then showing them that they had the necessary knowledge and tools to answer them. This kind of problem came to be named Fermi problems.

A very simple example of a Fermi question is „what is the mass of the Earth?'' That is a figure available in all sorts of books, which means that someone or even many people have, at least approximately, figured it out. However, how did they do it? Clearly, they did not find a spring scale and place the Earth on it, since there is nowhere to place the scale. In this sense, a figure like the mass of the Earth is much more difficult to access directly than the statistics about piano tuners in New York. On the other hand, it is far more concrete and easily estimated from common experience. (http://www.soinc.org/events/fermiq/fermiguide.htm)

In a Fermi question, the goal is to get an answer to an order of magnitude (typically a power of ten) by making reasonable assumptions about the situation, not necessarily relying upon definite knowledge for an "exact" answer.

- A Fermi question is posed with limited information given.
- A Fermi question requires that students ask many more questions.
- A Fermi question demands communication.
- A Fermi question utilizes estimation.
- A Fermi question emphasizes process rather than «the» answer.

Solving Fermi Problems is a great way to work on analytical skills and out-of-the-box thinking that leads to physical insight. One has to follow these steps: 1. Understand the problem: What information are you given? What are you asked to find? Do you need an exact or an approximate answer? 2. Look back: Does the answer seem reasonable? Is there a way to improve the estimate?

Shortly you have to:

Locate the information you need.

Decide what assumption(s) to make.

Estimate the solution to the problem.

Very important is the last step – to check if your estimation is reasonable.

## Fermi questions - competition

Fermi questions – a competition for secondary and high school students. There are several types of questions that can be answered by this procedure:

- Math (straight) – where the answer can be calculated using a calculator or computer but, since such aids are not allowed in the competition, it forces the student to consider other routes to provide a reasonable answer.
- How answers from one problem relate to other problems – as with many facets of life, an answer to one problem leads to many other choices and problems.
- Having solutions to problems relate to „real life", for example, a problem might ask for an estimate of the amount of gasoline used by passenger cars in France, how an increase in gas mileage would relate to a decrease in green-house gas production, and how the amount of water produced by same relates to other items such as rainfall or filling of swimming pools. (http://www.soinc.org/events/fermiq/fermiguide.htm)

Our competition started in 2007 and was announced via letters to all secondary and high schools in the address book of the Physical Olympiad and via the internet. The number of participants was very small – only about 30 students.

Some questions that were solved: How many hairs are on your head? What is the mass of a fully loaded Boeing 747? How many minutes do middle school students in your town spend on the telephone? How many 100-Watt light bulbs have the same energy output as the Sun? How many jellybeans fill a one-litre jar? What is the mass in kilograms of the students' bodies in your school? The evaluation was based on accuracy of estimation, number of supplementary steps in the solution to the problem (number of other questions and answers), originality, the presentation of the work. The students have to find any missing information, decide what assumptions make, estimate the solution to the problem and check that their answer is reasonable.

There were three parts in our competition. The first two parts were correspondence goals; the third one was the great finals. For „The great finals"the students were invited to our department at the Faculty of Science. Twenty students came to the last part of the competition. The results and the problems you can find at our web pages (only in Czech) http://isouteze.upol.cz/fermi/index.html. (Figure 1 and Figure 2).

**Figure 1. The Finals.**

**Figure 2. Solving the problem – experiment.**

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The second year the competition was tendered as international. In the cooperation with the Department of Physics at the University in Dresden (Germany), the competition was offered for secondary school students in Dresden. The number of participants of the second grade in 2007 in our republic was slightly more increasing (about 46). From Dresden we became only three works.

***An example - solution of the question „How many hairs are on a head? "***

One can compare the solution mentioned in the literature and the paper of our participant.

Solution (Goldstein, 1998): Where do you begin to answer such a question? Whose head is being discussed? Well, to begin with, since every head is different (from the thickest head of hair to the very bald) it must be assumed that we are going to take some average person's hair. The method we will use is quite straightforward. Namely, we will estimate the area of the scalp and then multiply by the estimated number of hairs in a small unit of area.

First, to get the area of the scalp we use a geometric approximation, which will be our model. We do this because the actual determination of that area would be difficult to make for any single head and because an exact result (say to 2-figure accuracy) would be representative of only that one head. Since heads vary in size even among adults (probably by 10% to 20%), the model will do as well for the approximation we're trying to obtain. Now the model is a hemisphere of the same diameter as a typical adult head. That diameter is about 10 inches or 25 centimeters. Check your own head by looking in a mirror with a ruler across your face. The surface area of a hemisphere of radius r is half that of a spere.

Area of hemisphere = 1/2 area of sphere = 1/2 x $4\pi r^2 = 2\pi r^2$. With the radius, r = 1/2 diameter = 5 in we get area of "scalp" = 2x3x $(5in)^2$ = 6x25 $in^2$ = 150 $in^2$. Next, we need some estimate of how many hairs are in a typical patch or unit of area. By counting the number of hairs roughly along a line of 1 inch, somewhere in the middle of your or your friend's scalp, you will get something like 15 to 40. Then squaring that, which assumes the hair is arranged somewhat like a checkerboard or grid, gives 225 to 1600 per square inch. Combining these two factors we have the number of hairs equals 150 in2 x (200 or 1600) $in^{-2}$ = 30,000 or 240,000 hairs. Note that I have rounded off the 225 to 200, which is justified by the large uncertainty in our estimates. The result is somewhere between 0.3 x 105 and 2.4 x 105 (using "scientific notation" for the powers of ten involved). We can say that the relevant order of magnitude is $10^5$.

Our student´s analysis:

It is necessary to calculate the surface of the head. We will use the formula for a sphere and calculate the surface of a sphere:

$S = \pi \cdot d^2$

$S = 3.14 \cdot 162\ cm^2$

$S = 803\ cm^2$

803 $cm^2$ represents one hundred percent (100 %) of the heads´s surface. The head is covered by hair only from about 40 %.

40 % is about 321 $cm^2$

1 $cm^2$ presents about 300 hairs

$321 \cdot 300 = 96300$ hairs

The result is – an adult has about 96300 hairs on his head. The relevant order of magnitude is again $10^5$.

## The competition Young Inventor

The aim of this competition is to organize a conference for secondary and high school students where they have an opportunity to present their works – inventions, improvement suggestions, ideas, results of their cooperation with concerns, etc. It is known that great ideas come from hard work. Through the process of putting students together, they show how they must apply knowledge gained from lessons in life science, physical science, and technics for solving problems. This experience will help them to understand the importance of invention, the scientific breakthroughs required creating an invention and how science relies on the constant improvement of its technological tools in order to progress.

Objectives:

- To heighten interest in science and invention
- To stimulate thinking about science and invention
- To use the interest in science to encourage academic growth in other curricular areas
- To increase self concept through participation in exciting projects
- To increase understanding of science concepts

The invention process provides an opportunity for all students to participate and be successful. Research has shown that inventing will enhance self-image, stimulate and foster creativity, relate the scientific method to real life, develop the essential skills of logical thinking, creative problem solving, intellectual risk-taking, and communication.

Students will also solve actual problems, develop higher-level thinking skills, use creative and critical thinking skills and learn to document the inventive-thinking process, develop public speaking skills.

## Judging

The judging process is an important component of the conference. Inventions are judged on the following:

*Originality* (Does the invention represent an original and creative thought? Is the invention a novel or unique solution to an identified problem? Does the overall presentation of the invention reflect creative or original work?)

*Usefulness* (Does the invention solves a problem or need? Does the invention have marketable value?)

*Written Description/Presentation* (Does the content of the written description clearly express the purpose of the invention and how it accomplishes its purpose? Is the written description complete?)

*Model/Illustration* (Is the illustration complete, with all parts neatly labeled, and is a clear attractive, visual explanation of the invention? Is the model and accurate replica of the idea?)

*Research Performed* (Was time and effort given to see if this invention had already been invented?)

*Construction/Complexity* (Does the construction match the design (diagram or display board)? Is it safe and reasonably well constructed?)
*Written/Oral Presentation, Creativity*

The first conference was held in November 2007. Works and inovations presented were on very high level. Very interesting was for example the presentation by David Spila (14 years old) – his project was an electromagnetic switch relay (Figure 3). The winner presented an electromagnetic pulse accelerator (Figure 4).

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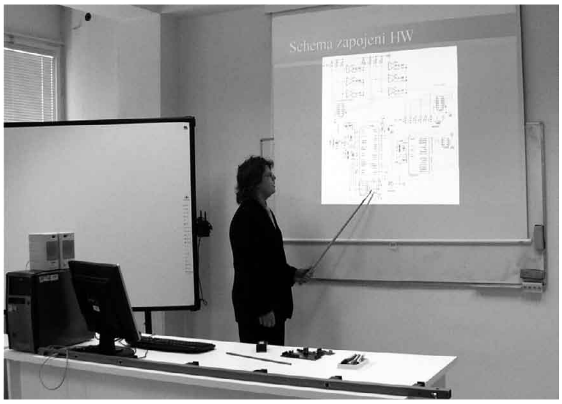


**Figure 3. The youngest inventor.** **Figure 4. Presentation of the participant.**

## Conclusion

Fermi Questions help to develop critical thinking skills with respect to estimation in science. It can be used effectively as early as grades 7 and 8 in elementary school, through all levels of secondary school, and well into the first two years of college or university. Our society may specify the minimum level of knowledge that any educated person should have. Very important is that every educated person should posses the curiosity and the ability to search for new knowledge, to explore the unknown by analyzing and assimilating new information. One good way is to ask questions.

Only a small number of students were interested in the competition Fermi Questions. The results in the Czech Republic and in Germany are the same. The competition The Young Inventor was more successful – the presented papers within the convention had shown a good quality of students´ knowledge, most of them cooperate with industrial enterprises.

There are many activities presented by our department – besides the competition Fermi questions and The young inventor, it is the initiative Researcher, the Trade fairs or demonstration shows with simple experiments, The physical kaleidoscope for high school students, open doors, workshops, The kids university etc. The future will show us if this is the right way for the recruitment of students and their motivation for physics and techniques.

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