# The Best from Science for Upper Secondary School

*Katarina Teplanova, (teplanova@fmph.uniba.sk), SCHOLA LUDUS - Centre for complexity in science education and non-formal lifelong learning, Faculty of Mathematics, Physics and Informatics Comenius University Bratislava, Slovakia*

## Abstract

The framework of the new SCHOLA LUDUS educational program designed for secondary school students is presented. The goal of the program is to interest students in modern physics and creative thinking. The program consists of different cases. Each case is based on ideas that led to the most respected scientific results which received awards such as the Nobel Prize. As educational method the SCHOLA LUDUS *creative-discovery modeling* is used, from simple brilliant ideas to surprising results. Students are inquisitive about the physical characteristics, phenomena and laws they have not learned about; they develop new basic principles; they model hypothetical situations related to nature and ingenious inventions. As an example, the case of Johannes Stark (Nobel Prize in 1919) is considered.

## Introduction

The framework of the new SCHOLA LUDUS educational program for upper secondary school students is presented. The goal of the program is to interest students in modern physics and science in general. The program ambition is also to fill the following three demands:

1. Urgent need for change of school science.
2. Urgent need to stop underestimation of students´ abilities to understand real problems and science.
3. Everyone has RIGHT to touch the best scientific culture, not to say general consequences and advantages for societies.

In the program the SCHOLA LUDUS educational approaches (Teplanova, 2004) are emphasized and applied.

## Vice Versa

Let start on the highest level of knowledge. The program should consist of scientific cases, each based on the most respected scientific results such as awarded by the Nobel Prize[1]. Each case should present "a detective story" on particular discoveries. There are many advantages of this choice of the content: a guaranteed correctness of the original sources, serious overview of the scientific theme, key role of the new results for science, technology and society. Another advantage is a motivation atmosphere that can be created introducing the Nobel Prize and related ceremonies at the beginning of the program. This atmosphere cannot be substituted by anything. Then the possible doubts of the adequacy of the program can relate the concrete contents of the teaching material, training of teachers and students understanding.

## Program Contents

A thread of any case of the program is based on readings from a chosen Nobel Lecture given by one awarder. The thread of the case could be completed with the introductory Presentation Speech or Interview and the Biography or Autobiography of the awarded scientists. By this the case surely includes

- a brief summary of the respective science knowledge to the date of the discovery and to the date of the Lecture;
- creative concepts and experiments that led to the new discoveries, including scientist's errors;
- consequences of the gained results for science, technology and society to the date of the Lecture.

Many concepts in the frame of readings are for students new. But they should be introduced and discussed only according to students´ questions and possibly in two views, from the point

[1] http://nobelprize.org

of view of their original and present meanings.

**The role of the teacher**

The success of the program strongly depends on the teachers! The teacher is a guarantee of a festive and creative class atmosphere. He/She provides catchy suggestive readings of the basic materials, animates students discussion and warrants students´ correct understanding of the used scientific knowledge. He/she is also an instructor for the development of students creativity skills, for example in accord with Edward de Bono (1992). No multimedia materials, models, games etc. could substitute this teachers´ function! The role of the teacher is to evoke "a lively performance". His/Her teaching process should become a real adventure of discovering the secret codes of nature that causes students´ vivid imaginations of scientific concepts and their importance and vivid impressions from the process of their getting. Who would stay indifferent to „Dan Brown"? In fact, this is a difficult task that requires support by educational multimedia, games etc.

**Students**

Students should be invited to questioning, predicting and modelling. They could start on the level of the simple brilliant ideas of outstanding scientists and get to their "own" surprising thinking results. Student should be also invited to design models of science, technology and society for two different paradigms:

1. for hypothetical developments if the particular discoveries had not happened;
2. for further developments associated with the discovery.

These exercises should support students overview, creativity and responsibility and can be used also for self-evaluation of students´ knowledge and/or for their examination.

**Whose Case?**

The Nobel Prize has been awarded since 1901. Any case is excellent. Let focus only on physics. Whose case is the most exciting? Whose case is the most important for general education? Whose case is the most inspiring for future scientists and technology designers? The number of cases during a school year is limited and depends on the level of the students.

**The case of Johannes Stark**

*Ladies and Gentlemen.*

*The Royal Academy of Sciences has decided to award the Nobel Prize in Physics for 1919 to Dr. Johannes Stark, professor in the University of Greifswald, for his discovery of the Doppler effect in canal rays and of the splitting of spectral lines in electric fields. It is only rarely that the study of a physical phenomenon has led to such a brilliant series of important discoveries as that which follows... The electron theory with its concept of the constitution of matter has become of radical importance to both physics and chemistry...*

Johannes Stark realised an *epoch-making research… the Doppler effect in canal rays has given us an insight into the reality of the internal structure of atoms and molecules. …the splitting of spectral lines in electric fields* is *a discovery of the greatest scientific importance.*

*Features of Stark´s Work*

What could students learn from Johannes Stark Nobel Lecture: *Structural and Spectral Changes of Chemical Atoms* (1919)? Besides a brief summary of the respective most important facts until 1919, they can get out and identify features of qualitative development of scientific knowledge in general:

/His view was interdisciplinary - atomic physics, chemistry, electricity in gases, optics, spectroscopy, crystallography. /His view was dynamic. In his task he focused not to separate states (of atoms) but to a process - the change from one state to other state. In addition, he considered that both cases are not steady but changing during the process. /In order to define his tasks he needed to gain an overview. He supposed a relation

between the change of atomic structure and the change in spectra of chemical atoms. /Also the questions were focused not on one state of atoms but much more effectively - on two parallel states at once and on their relationship: 1.What are the two spectra which belong to the two atomic structures - to neutral atoms and - to positive atomic ions? 2. Is a specific spectrum emitted if the positive atomic ion is changed into a neutral atom? */He answered his two questions first by forming two hypotheses. This step was very important* ..in order to be able to think out a specific series of experiments to test these hypotheses. /He realised *…that the second of the hypotheses was wrong, and neither bore it experimental fruit. /*He was ready to formulate another assumption - *that is, the assumption that energy is emitted in accordance with Planck's quantum law through an electron changing orbits about a positive charge.*/He compared his results with results of others. He found an analogy *to Zeeman's discovery of the splitting of serial lines by means of an extremely strong magnetic field.* But he recognised an important differences: *The optical dynamics of the atoms alters, under the influence of an electric field, in a manner quite different from that under the influence of a magnetic field.* How many analogies in the history (not only of science) were wrong? */He must be very creative. Let us consider the simple idea of ions accelerated by strong electric field as light sources moving with defined velocities, the variation of measurement of light in two directions - forward and perpendicular, etc.*
Notice. Above is a list of some features of Stark's work that is addressed only for teachers. The aim of this is to turn the teachers´ attention to different moments that should be emphasized during the educational process. If these features had been given one after another in the above way the educational effect would be poor. Curiosity and surprise are missing. In the frame of the educational program the story should be interrupted by questions. For example: "What do you mean, what could be the Stark's next step?" Or, "What would be the answers to the Stark´s questions today?"

*An extra message*

We found one extra message from the Stark´s ideas relevant for today´s era of wireless technology that touchs everone:

*"We must always bear firmly in mind that the chemical atom is an individual, self-contained structure of positive and negative electric quanta. An external electric field, meeting it and passing through it, affects the negative as much as the positive quanta of the atom, and pushes the former to one side, and the latter in the other direction… ."* This displacement *"...means a deformation, an alteration of the atomic structure in comparison with its form before the influence of the external electric field."*

*Current achievements*

Another challenge for the program and students is represented by the recent achievments in science and technology connected with the awarded results.
Stark was surely aware of the value of his results but he was aware also of number of new open questions. However, his following prediction was "too pessimistic":
*„It is more likely that more than a century will pass before we know the structure of the chemical atoms as thoroughly as we do our solar system. Many scientists will have to contribute to the solution of the great problem; they will have to follow up and measure all those phenomena in which the atomic structure is directly expressed*. "

Stark would be surprised by the progress of science and modern technology, lets mention three cases:

1. The active use of Doppler effect by methods to cool and trap atoms with laser light developed by Steven Chu, Claude Cohen-Tannoudji and William D. Phillips (The Nobel Prize in Physics 1997)[2];

[2] http://nobelprize.org/nobel_prizes/physics/laureates/1997/

2. The Optical Atomic Clock - a result of the work of John L. Hall and Theodor W. Hänsch on the development of laser-based precision spectroscopy, including the optical frequency comb technique (The Nobel Prize in Physics 2005)[3] and
3. The Quantum-Confined Stark Effect that occurs in a semiconductor heterostructure. The effect is widely used for semiconductor-based optical modulators, particularly for optical fiber communications[4].

The last example is important for student also because this is an example of outstanding results that were not awarded by the Nobel Prize. Students should become aware that science means also competition and not each result could be awarded by the Nobel Prize. The science means hard work and personal challenge, and - it is human.

*Stark´s Human Failure*

Dealing with Stark his human failure - the leadership of "*Aryan physics"* against the *"Jewish physics"* cannot be hold back[5]. This sad story belongs also to the history of science and "the looking for its historical roots" should be also a very important part of the educational program.

## Examinations

Two ways of examination are considered at the moment:

1. Indirect evaluation of understanding the key discoveries through their wide consequences. This way is based on the above mentioned students´ models for hypothetical development with, and without, the respective discoveries. The gained two, mutually confronting views allow to evaluate understanding and also broadness of students´ conceptions and their operational potential.
2. Evaluation with parallel cases (for example see Biznarova&Teplanova 2004) on basic features of the respective discoveries at different conditions etc. In *The case of Johannes Stark* the tests could relate e.g. comparisons and interpretation of the mutually shifted spectra (the Doppler effect); basic facts, hypotheses, principles, conditions that enabled Stark to prove the Doppler effect; modelling Doppler effect for different cases of an macroscopic source and for cases of microscopic sources.

## Conclusion

"The SCHOLA LUDUS Best from Science to Upper Secondary School Program" is considered as an open program. It is open for a choice of the case of the Nobel Prize awarder and it is also open for contents of each case. For classes, one case is meant as an educational block that run like a series of creative-discovery workshops with one thrilling thread that is tracking over the scientists' trail and students´ here-and-there excursions to unknown fields. It is a program full of questions and answers including valuable information, proceedings and messages depending strongly on teachers attitudes.

It is not probable that in schools we can go through a whole Nobel Lecture but it is possible that some of students will continue...

Also, let us dream: Bringing Nobel Prizes from all fields into upper secondary schools...

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[3] http://nobelprize.org/nobel_prizes/physics/laureates/2005/

[4] http://en.wikipedia.org/wiki/Stark_effect

[5] http://en.wikipedia.org/wiki/Johannes_Stark