**THESES**

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# Raising Students' Interest about Physics by Building an Educational Space Probe Model and by other motivating methods


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# Introduction

The “Technical Society” –as the name suggests– is built on the wide variety of scientific achievements, which has deep roots in physics. Recognizing the essential role of physics, it forms a vital part of the curriculum of the BSC courses at the technical colleges and universities. In the reality, that was the case some decades ago. Unfortunately, nowadays physics has eroded in the education. As a result, the students’ knowledge and their motivation as well is very low.

Although in the 21th century, in the so-called Space Age, we are more and more technology dependent (computer, smart phone, IoT, etc.), at the same time, the interest in science and engineering among pupils is going downhill. This is a worldwide phenomenon, and things are going from bad, to worse. Based on my years of experience, the situation mentioned above is the root of many problems. Moreover, after one or two years in higher education, the students have lack of system approach. In my dissertation, I present the methods and programs in which I try to raise attention and interest about physics among my students. Sometimes directly, sometimes indirectly.

By now space research almost became a daily routine, but it still could be exciting, especially if the media directs focus on it. Recognizing this situation I proposed an educational space probe building project in our Institute. The so-called HUNVEYOR project is a minimal space probe construction program, which is running parallel in several educational institutions in Hungary. The name “HUNVEYOR” stands for Hungarian UNiversity SurVEYOR. The program was initiated by Szaniszlo Bérczi, by my supervisor at the Roland Eötvös University, Budapest in 1997. The Hunveyor-1 had a camera and telescopic arm as instrumentation. Later on we developed a rover for the project, along with a test-field. Since then other Hunveyors were built with their own electronic and experiment constructions. The second one was built at the Pécs University (Hunveyor-2), and the third one at the Berzsenyi College in Szombathely (Hunveyor-3).

The Alba Regia Educational Centre of Óbuda University (once called Budapest Polytechnik Kandó Kálmán Faculty of Electrical Engineering, Institute of Computer Engineering) joined to the project with the Hunveyor-4 in 2001. I have been leading this project for more than a decade now. The project is an educational experiment, and consists of the engineering and the building the probe itself as well as the public outreach, through experience based on indirect physics education. The constantly evolving project has incorporated individual solutions to complex problems.

No one should seriously think that our HUNVEYOR-4 space probe will fly in space. The primary teaching aims of the HUNVEYOR project at our Institute are:

- to raise interest among young people age 15 to 21
- to make science and engineering career attractive
- to form an attractive, meaningful and long term framework for the research and development carried out by our students
- to provide personal experience
- to develop skills in engineering, organization and realization of products
- to get acquainted with the latest technologies
- to involve students in research and development
- to study real, complex situations, not pure „sterile” physics
- to offer subjects for diploma and other project works
- to serve as reference in job hunting

Of course our students will not become astronauts or geologists, but electric engineers. Yet the project is part of the "Space Education Program" that will improve students' engineering skills through building different sensors, instruments and designing software. While these goals have not changed over the years, the HUNVEYOR-4 did evolve.

In order to help my students better understand the basic concepts of physics, and to show how to apply the main principles in practice, I often give demonstrations in my lectures. I developed some new experiments. They make my explanations more colorful and memorable. In my dissertation, I present two of them. One helps to understand the different magnetic configurations and the magnetic properties of matter by visualizing the magnetic field. The other demonstration deals with particle radiation.

Visualizing the magnetic field can help physics teachers to inspire students in their learning. In my experiments I use the so-called Buckyballs (or Zen Magnets), relatively newly developed super-strong magnetic balls in different arrangements, and a magnetic-field viewer film. The film responds to the magnetic field by changing color. Over the poles where the magnetic field is perpendicular to the plane of the film, the film turns dark green. Where the field lines are running parallel to the plane of the film, the color becomes lighter. If we use the magnetic balls as identical building blocks we can create two-and three-dimensional shapes or patterns. In these shapes different symmetries (translation, rotation … etc.) as well as crystal faults can be recognized. Unlike in crystallography however, in our case the number of possible combinations are strongly restricted due to the mighty magnetic properties of the balls.

We have no sensors with the ability to detect particle radiation. We have no firsthand experience about this phenomena and thus we have no understanding when fear is necessary. The media tend to overreact and cause panic, even when there is no reason for it. In education, it is important to adequately deal with the issue. Studying the frequency, distribution, and evaluation of the statistical nature of the radiation can help in everyday life in the correct interpretation of half-understood, or intentionally misinterpreted information, coming from sensation hungry news channels.

In my second demonstration I record to a computer the typical ticks of GM tubes which mostly used for detecting particle radiation. I can record the background radiation on different locations such as in the house, in a basalt mine, and on a high-flying plane in advance. Because I record the ticks using a free audio processing program, the frequency of the beats can easily visualized, and visually compared. Moreover, because the time of the ticks can exported to a text file, the recorded data can be processed and statistically analyzed. My method promptly visualizes how the atmosphere protects us against the deadly cosmic radiation.

Searching for extraterrestrial life and intelligence is an actual and fast developing research field of science. The first step is finding earth-like planets around alien stars. I developed a teaching material for this. I summarize the necessary background along with 24 detailed numerical exercises, in order to explain the main methods in this field, and to show the tremendous difficulties. Some part of the material is suitable for beginners, but others give~~s~~ a challenge even for talented students.

The most successful method finding exoplanets today is the so-called transit method. I developed a simulation in EXCEL to demonstrate and to study the brightness variation of a star in case its dark planet transits in front of it. I explain the computational method in chapter three of my dissertation. I also explain how to use the program.

Under the “Teaching Physics” doctoral program, there was a nationwide survey among high school students-about their imagination of the energy, the basic concept of physics in the year 2011. The questionnaire had 15 questions. I joined the survey with asking the same questions my students before and after the physics course. I conducted this research for several years. I discuss the results in chapter four of my dissertation.

## The goals of my research

I set the following goals in my doctoral research:

1, Finding a topic and elaborate methods for BSC students choosing electric engineering as major, which is suitable to gain their interest to keep it high about how nature works. At the same time, the knowledge of physics of the self-motivated students can significantly improve.

2, Developing and using novel demonstration in classroom, making physics more interesting in order to counterweigh the poor situation devolved in the science education, mentioned before.

3, Developing detailed teaching material for gifted students, which numerically explains the difficulties of finding Earth-like exoplanets, which is a hot topic of actual scientific research.

4, Surveying the energy concept of my students at Óbuda University, learning in BSC education.

In my dissertation, I reported my more than a decade long pedagogical efforts, and its results. I demonstrated that my goals (i.e. deepening the knowledge of my students in physics) could be achieved by taking part in the HUNVEYOR project, using novel classroom demonstrations and extra-curricular education. In some cases I surveyed the knowledge of my students and the improvement of their knowledge by using questionnaires.

## Theses

### 1. The HUNVEYOR-4 educational space probe project:

***1a, I found, that the mere call for building a space probe was not enough motivation for the students. After a grace period a second call along with a demonstration of a strange-looking frame built from aluminum was successful. From this experience I concluded, that not even the best BSC students can be attracted by a dry, abstract topic. Their fantasy needs concrete things, to grasp the possibilities and to join into a project in a constructive manner.***

The call for the project stated: Suppose that we intend to send a space probe to an extra terrestial object, such as the Moon, Mars, or one of the moons of the Jupiter, Saturn. The main job of the probe is to collect information in order to prepare the future colonization of the object. The probe should take different measurements and analysis and send the results back to Earth. The probe should be remote controlled via internet.

***1b, I showed, that the students were able to engineer and construct the functions of a space probe, taking account of my hints and instructions. They were able to choose the appropriate building elements, and they were able to construct and integrate all of it into a working system. The probe reproduced, in some cases even exceeded the functions of the Surveyor-7, which was the template for the project.***

The main job of a space probe is to collect and beam down visual and numerical data about its environment. The basic role of the Surveyor-7 was the analysis of the soil on the Moon. In addition to Surveyor-7 the HUNVEYOR-4 had much more capability, thanks to many other equipment and communication capability naming a few: meteorological station (temperature, wind speed and direction), humidity, air pressure, humidity), gas composition, noise level, lightning detector, insolation, brightness and spectral composition of illuminating light, LED spectrometer, earth quake detector, particle radiation and dust particle counter. The control of the space probe, the data collection, and communication based on a PC motherboard.

***1c, I found, that the physics knowledge of the students significantly deepened by engineering and building the instruments.***

The physical knowledge of the future electric engineers improved in many different ways. During the project, there were no formal physics lessons, but a lot of project leader – student and student -student discussion took place in a brainstorming manner. The students also browsed the literature, regarding to the different sensors, instruments and their capability. They also learnt a lot of physics during engineering, building and testing their specific devices. They also made progress on the field of creativity.

***1d, By building the Hunveyor-4, the students' system approach has evolved.***

Usually the students focused on the development of the devices only when solving a given task. In the case of HUNVEYOR-4 they even had to take into account that the separately designed and built instruments should work together in a single system as a complex unit. E.g. each device needs energy, receives commands and provides data on request or even automatically. Not all devices can work simultaneously, so the probe as a system needs allocation of different resources (energy, communication time slices, and so on). At the same time, the probe itself is part of a bigger system, because it is hooked up to the Internet.

***1e, Using the Hunveyor-4 educational space probe, I extended the laboratory exercises into open field physics experiments.***

There is a program called "Open Field Physics". This means, the experiments and measurements take place in a complex environment, without avoiding any disturbing circumstances, i.e. not in a "sterile" laboratory. This kind of measurements happened during the field exercises. For example while the students measured the soil composition using the robotic arm, the air blasts disturbed the measurement heavily. All this experiences enriched the concept of the real measurement in the students' mind. Moreover this kind of work was always more memorable than the classroom experiments.

***1f, I proved, that the Hunveyor-4 robotic space probe served as an opportunity for a remote controllable simultaneous measurement of multi parameter processes for the BSC students. This kind of measurements was not available in the education before.***

The task for a robotic probe is to give measured data about its environment. We need these data usually at a moment and from a place, which is unreachable for the traditional education. The Hunveyor-4 is a solution in these kind of situations. The successful participation in the MARS-2013 campaign is a proof for that. The Austrian Space Forum (Österreichisches Weltraum Forum - ÖWF) – in partnership with the Ibn Battuta Center in Marrakesh – conducted a Mars analog field simulation exercise in the northern Sahara, Morocco during February 2013. This place and its climate at that time is very similar to the climate on Mars during Martian summer. The HUNVEYOR-4 was participating in the campaign. The communication to the probe was established via satellite connection. During the field exercise, many environmental parameters were recorded. We also analyzed the quality of the link between the probe located on the "Mars" and our "Terrestial" computers.

Related publications: [1], [2], [3], [4], [5],

## 2. Classroom demonstrations in physics

***2a, In the teaching of magnetism I have introduced the use of the magnetic field direction indicator film. The magnet-film is an excellent tool for visualizing the magnetic field of different magnetic arrangements. The method is suitable for deepening the students' magnetic field concept.***

The magnetic field can be visualized in special ways. One way is the liquid iron, or ferrofluid, another way is the magnetic field viewer film. The latter is much more clean solution for classroom demonstration. The film makes the slices of the invisible magnetic field visible for the eye. During the demonstration, the students form a wide variety of 2D or 3D shapes from the extremely strong magnetic neodymium balls, and visually check the magnetic field around the balls. The visual method and personal experience help deepening the students' concept about the magnetic field.

Related publications: [6], [7].

***2b, I set out a very simple and easy to use method for analyzing the particle radiation. The method is fun and permanent experience for the students, because integrates the visual, audio and mental perceptions of data.***

I can show a graphic, or even quantitative results of the recorded ticks of a radiation monitor device using the free downloadable Audacity sound processing program. The record can be a prompt measurement or a prerecorded one. The different records can be played back, or the sound tracks can be placed under each other and we can visually compare, or even zoom in for studying in details. The pictures speak for themselves. Moreover, the time data can be saved to a file for further analyzation for example in a spreadsheet program.

Related publication: [8].

## 3. The difficulties of finding Earth-like exoplanets

***I worked out a series of numerical exercises to show the physical conditions necessary for finding Earth-like exoplanets. The numerical values help understand the extreme difficulties of the research. The topic is suitable for deepening the students' physical knowledge in advanced level. As far as I know, this kind of teaching material did not exist~~ed~~ before.***

In the absence of other known place that has life in the Universe, the generally accepted opinion is, that life can be find only on Earth-like planets. My exercises based on this concept too. The 24 exercises range from easy to hard and are suitable for deepening the concepts of physics. At the first part, I summarize the background knowledge, like wave optics, Airy-disk, optical resolution, Rayleigh criterion, black body radiation, and so, followed by imaging devices, like CCD. I explain direct and indirect methods as well. I mention astrometric, photometric, and spectroscopic methods, and the Doppler and Rossiter-McLaughlin effect and their use in research. For the numerical evaluation of the exercises, I use the parameters of the Hubble space telescope and the Solar system. In addition, I developed an EXCEL simulation to demonstrate and study the transit method. I tested this material in astronomy study group sessions.

## 4. Survey of the students' energy concept

***4a, I surveyed my students' energy concept and its evaluation. For my survey, I used the same test that was used for a nationwide survey among high school students. I found, that the energy concept of the BSC students' choosing career in technical fields (namely electric engineering and informatics) is not better, than the average in middle school. However, after a physic course, which lasted one semester they performed significantly better.***

The test consisted 15 questions. I conducted my survey for several years. In order to monitor the changes of the students' knowledge, I tested my students before and after the physics course. I evaluated 327 questioners. I examined the following categories: a) the number of correct answers, b) knowledge of scientific facts, c) knowledge of concepts, d) numerical calculations. I found, that after the physics course my students' knowledge improved by 26%.

***4b, I found, that the knowledge of scientific facts and concepts are slightly better of former students, graduated twenty years earlier, but their numerical calculation is at the same level as the students today.***

For further study, I was able to test practicing electric engineers, once my students, graduated twenty years earlier. After evaluating 33 questioners, I found, that they performed ~~a~~ slightly better in some field than my current students. My opinion is, that was a result partly of the better education, partly of wisdom, a 20 years long life experience.

## My plans for the future

I will continue my teaching and organizing activity on the field of education, using my life long experience, especially on the field of physics and astronomy. I offer more projects for my students, especially in the framework of the HUNVEYOR-4. That means for example a mobile data-collecting device, a wirelessly controlled rower, and a sand table, simulating different terrains. Moreover I plan to set up a Foucault pendulum, suitable for computer analysis of its movement, and another experiment using CCD camera and image processing of black body radiation.

## Publications for the theses.

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