Informal Physics Education and Teachers' Training – Some Examples and Experiences

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1. Introduction: where, when and what

In this article I will describe 3 intertwined activities concerning informal physics education and training of physics teachers:

- Summer math-phys camps for high school students
- Spring camps for future physics teachers
- Activities in Heureka project aimed at teachers at schools

Some of them were already shortly mentioned in [1] and [2]; here they will be described in a bit more detail. To put them in some context it is perhaps reasonable to start with the information where and since when we organize them.
Our activities are aimed mainly at Czech students and teachers so they take place mostly in Czech Republic – not only in Prague but also at various other places. Perhaps it is worth mentioning that several teachers from Slovakia are also involved and we try to attract other foreign visitors to some seminars.
The origins of our activities can be traced to 1980's or even to previous years. They evolved from small roots (popular lectures on physics, physics clubs for high school students, then first summer camps etc.) to more sophisticated forms. In about last 3-5 years they may be regarded as quite "mature" but we still learn how to do them better and more effectively, try to find new inspiration, add new perspectives… We feel to be not at the end but on the road.

■ What can emerge from such activities: First example

The important point in most of our activities is the fact that the participants should "touch physics with their own hands". Often it is meant very literally – and sometimes it can lead to unexpected and inspiring results.
The purpose of the first version of the indicator described below (with just 2 transistors, see Fig. 1) was just to show people that they are not "infinitely resistive", i.e. that a small current can go through their bodies. The scheme was quite simple and also the construction was transparent: a small wooden plate with several brass nails in it to which pins of transistors etc. were soldered. No black box, everything clearly visible.

Trying to increase the sensitivity I added the third transistor and discovered it is so sensitive that it reacts to electrostatic charges!
The scheme shown at Fig. 2 was already published in [1] (and in Czech in some proceedings before); here I add some comments on its use.

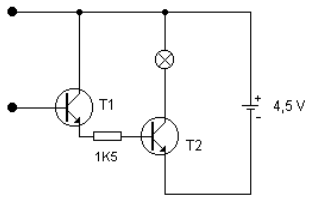

Fig. 1: Simple version of the indicator

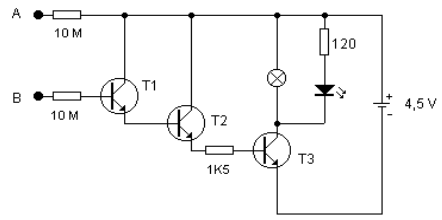

Fig. 2: Electrostatic indicator with bipolar transistors

You can use this scheme as an indicator of conductive connection between contacts A and B with resistance of the order of GΩ or less. Or it can indicate small currents with the sensitivity of the order of 1 nA. (If you unscrew the light bulb, the sensitivity is higher.) You can demonstrate charging and discharging of the capacitor made from two aluminium foils separated by a thin plastic foil. (The indicator may serve better for this purpose than a normal multimeter because we can see even a short flash of a light bulb or a LED.)
Finally, you can use it to indicate an electrostatic charge – or rather the changes of the charge. Connect a piece of wire (10-20 cm) to the contact B. Now rub the plastic rod and move it closer and farther from the wire. You can discuss the results with your students: Why the indicator with NPN transistor flashes when the plastic rod moves *away* from the contact B? How it would be with a glass rod? The advantage of our indicator is that you can clearly determine the polarity of the charge – your students see that the bulb shines if they connect contact B to a *plus* pole of the battery (i.e. in case the charge flows *into* the base of the transistor T1).
It is not the purpose of this article to discuss in more details this or further experiments with the indicator. I just wanted to illustrate that the intention to give students and other people something simple to touch may sometimes lead to a nice experimentation and to further interesting and perhaps useful results

2. Summer math-phys camps for high school students

Can you imagine a group of 30-35 high school students (14-19 years old) voluntarily spending part of their holidays with mathematics and physics? (Well, you, reader of these proceedings, probably know many such young people...) In fact, our Faculty organizes 2-3 summer math-phys camps. I will describe here one a bit special.
Our summer camp takes place every July at various places outside Prague, lasts two weeks, combines scholarly and non-scholarly program and in last years it is aimed at *projects*. (See web pages [3]. It is mostly in Czech but there is also a short English summary and the photographs speak about the atmosphere more than words can tell.)

How it all evolved:
The tradition of our summer camps lasts for more than 20 years. For years the program consisted of lectures + some sport and games. (I remember that, inspired by my former physics studies, I gave there lectures on relativity, curved spacetime, black holes and cosmology...)
Then some seminars and exercises supplemented the lectures and games became more sophisticated. (We found it useful to let participants learn actively some introductory parts of

calculus as well as to let them relax by playing challenging games, sometimes even during part of the night.)
Then we realized that, to some extent, "all theory is gray and green the golden tree of life" – and we added some physics experiments to our scholarly program. And, gradually, experiments started to play more and more important role in it. (Well, cosmology is very attractive but sometimes it appeared that for some participants it was so easy to just talk about it. And we realized that to do something with their own hands would be for students more useful and important.) About ten years ago also the games started to be combined into one "camp legend".

What is the "state of the art" of our summer camps:

- There is one main theme of the scholarly program (different for each year).
- There are math and physics courses (each course in 2-3 levels).
- Several "special lecturers" (scientists from various scientific institutions) give their lectures (some of them as optional lectures in the evening).
- The important component of our camp is projects. They take about half of the time of the scholarly program.
- The participants present results of projects at final conference.
- The games and other activities of non-scholarly part of the camp are connected by one sophisticated legend or "camp game", also different in each year.
- In the non-scholarly program participants form several teams which have to both compete and cooperate. It must be said that the non-scholarly program does not mean only distraction and relaxation. It is also "delicately" aimed at personality growth of participants, helps to develop their communication skills etc. etc.
- The non-scholarly program culminates in one complex large final activity, which may last up to 24 hours or be challenging in other aspects.

To be more specific, let us look at the main themes and non-scholarly program legends of our camps in last years.
Main themes: Let there be *light* (1999), *Time* (2000), The music of spheres (*sound*, 2001), $E=mc^2$ (*energy* in all forms, 2002), *Forces* and interactions (2003), Smaller and *smaller* (2004), *Resonance* (2005).
Themes of legends: Old Greece (1997), The Holy Grail (1998), "Legend without legend" (1999), Expedition to the Past (2000), The Unseen University (2001), Old Mayas (2002), Treasure Island (2003), The three musketeers (2004), Colonization (2005).

As it was already stated, specific and very important part of our camps is active work on *projects*. Our projects are:

- Open. (They are not strictly directed according to fixed instructions. Sometimes the results of a project are new and inspiring even for the organizer who suggested its theme and took care of it.)
- Based on team work. (They are solved by groups of 2-3 participants, only sometimes there is "one member group".)
- Requiring active work. (Each project has one consultant from the team of organizers. We deliberately do not call him/her the "leader" of the project. He/she should be rather a guide who helps participants to solve the project.)
- Developing cooperation instead of competition. (There is no contest at the end but he conference where all participants can appreciate results of other groups.)

- Aimed at both work (which is most important for the participants) and the results (which are sometimes so inspiring that they may be presented also at other conferences and seminars after the end of the camp).

Examples of themes of projects from various years include e.g.: Catapult, Steam engine, Compressed-air motor, Solar stove, Electrometer, Energy of a man, The speed of sound, Fourier analysis, Various loudspeakers, Oscillations of a string, Sirens and a model of Hammond organ, Laser microphone, Foucault pendulum, Forced pendulum, Measurement of solar constant, etc. Altogether there were more than 80 projects solved at our camps in last 7 years.

Could we generalize some *experience* from the camps? Yes. Here is what we have found that works:

- It is important that there is not only mathematics and physics there. Non-scholarly program is equally important. It helps participants to cooperate, freely communicate with each other and unites all people together. (Especially for some students more oriented to "hard science" it is quite important to develop these and related competencies!)
- Mixing students of different ages (from 14 to about 19) works quite well both in non-scholarly and scholarly program.
- Several levels of math and physics courses offered to the participants proved to be very useful.
- An active work on projects is appreciated by the participants a lot. But to do only projects would not work well. A proportion of time devoted to projects and to other activities of scholarly program of about 1:1 proved to be optimal.

Of course, such type of summer camp is quite demanding to preparation, organization etc. There are several key points we found necessary for a successful run of the camp:

- Good team of organizers! In our case it consists of two subteams: for scholarly and non-scholarly program. Together it is about 16 people.
- Suitable place for the camp. We need rooms for a "lab" (for more than 30 people), small workshop (for harder work), at least 2 lecture rooms – and a neighborhood suitable for games and activities of a non-scholarly program. And, of course, the price of accommodation should not be prohibitive and the personnel must be tolerant to our experimentation and a lot of "non-standard activities".
- Material support. The projects (especially open ones) require a lot of material and equipment. We also take with us several tens of books, some computers etc.

What is perhaps not strictly necessary but useful is a *change* and *evolution*. We try not to repeat things and activities routinely – to make our camp interesting both for participants who come again next year and also for us. In fact the need for change I perceived was the reason why I passed the leadership of the summer camp to younger generation in 2004 – and it really proved they have new nice ideas! We all hope the summer camps will evolve further in the future. See [3] for both the history and future plans.

■ What can emerge from…: Second example

As it was already stated, the work on projects on summer camps sometimes leads to new inspiring ideas, experiments (or variants or details of experiments etc.). As an example I will shortly describe an instrument which developed from one project I led at the camp with the main theme Sound.

I call the experiment “A singing Styrofoam plate”.

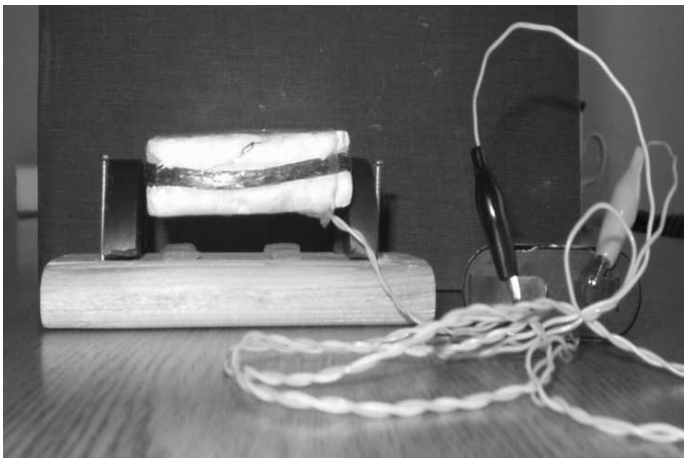

Fig. 3: “A singing Styrofoam plate”

Wind several tens turns of a thin isolated (enameled) wire around a small Styrofoam plate. Put the plate between two magnets. Now, if you connect the ends of this coil (via a thin flexible cable) to the battery, you can see that Lorentz force pushes the plate up or down (see Fig.3). If you switch the current on and off, the plate moves back and forth – it would vibrate if switching was fast enough. In fact, you now have a simple model of an electrodynamic loudspeaker. Connect the contacts to the output of an amplifier and put some music signal into it – the plate, your speaker, will play and sing! For a lot of people it is quite surprising but it is really so.
Some technical comments should be added:
The wire of the diameter of about 0.2 mm works well. Check the resistance of your coil. It should not be too low not to damage your amplifier. Too large resistance lowers the output power. About 10 Ω is a reasonable value. What is very important is to fasten the wire to the plate – otherwise it is just the wire that vibrates instead of the entire plate and the sound is barely audible. A good solution is to wound the plate with wire by a plastic tape. Anyway, do not expect any loud sound from your speaker. But in a silent room (even in a classroom) you can hear it quite well.

3. Spring camps for future physics teachers

More than eight years ago we decided that various activities done at the summer camps would be extremely useful for future physics teachers – i.e. in pre-service training of teachers at our faculty. That is why we started an informal “spring camp” for future physics teachers.
First one, in 1997, was nearly a private “business” with just 10 people (both organizers and participants). Next year the number of participants was higher, then even higher… and the spring camp became a tradition. At present years the number of participants settled at about 30.
The spring camp is shorter than the summer one, lasting just 4-5 days at the beginning of May. And it takes place in much “modest conditions” – two wooden shacks, no personnel to care for kitchen and accommodation etc. etc. (See web pages [4], again in Czech but again with photographs showing a lot about the atmosphere of the camp.)

The "philosophy" of first years of our spring camp was shortly described in [5]. Now I would like to add just some more comments. The participants are students, Ph.D. students and also some teachers from schools, mainly former students of our faculty. We return to the same place near a small village Mala Hrastice, less than 40 km far from Prague. There are really not luxurious conditions there but a beautiful countryside. It is an ideal place to check whether physics works not only in school labs but also in the real world – with very simple instruments and equipment.
There is again scholarly as well as non-scholarly program at the camp, both *very* informal. Scholarly program has a form of "miniprojects" often having rather vaguely suggested themes. Students in small groups choose what they would like to do, to try, to investigate… There is no formal conference at the end, however, each day in the mid-afternoon we present each other what we did. In last years the main theme of the spring camp was the same as the theme of the summer camp – and the spring camp proved to be the ideal "laboratory" for developing, "tuning" and "debugging" the ideas of projects for the summer. But it is much more than that. It is also an ideal environment for removing various barriers: between "school physics" and "real world", between "university physics" and "physics for high schools" and, last but not least, between "us" and "them" in many senses of these words.
Again, what works proved to be: an informal atmosphere, collaboration, mixing of students of different ages (from 1st course to Ph.D. students), usage of simple tools and instruments, often made at the place, non-scholarly program as an essential part of the camp.
The results are encouraging. Students like to return to the spring camp. And I must say we like it too. To put it a bit poetically, we may say that for us Mala Hrastice is not only a place, but rather the state of our souls and the approach to people and to the world… To be more pragmatic: The results are so encouraging that we already started other – not a whole camp but a weekend – for students who will become students of teaching physics (i.e. just before they enter the 1st course at the university).

■ What can emerge …: Third example

As an example how "miniprojects" can be inspiring a simple model for demonstration of waves can be shortly mentioned. We can demonstrate both traveling and standing waves at the piece of rubber rope – and show how it is possible to measure the frequency by an ordinary ruler!
Take about 5 m of thin rubber rope (may be obtained in haberdashery as a rope to anoraks etc.), fix one end and hold the other end in your hand making the rope moderately stretched. Then, moving your hand quickly up and down (or using the other hand) you can create the pulse which travels along the rope, bounces at the other end, bounces at your hand etc. You can measure the total time till ten returns to your hand (the total length being 100 m for 5 m long rope) and so determine the velocity v of traveling waves. (It depends on the tension of the rubber rope; usually it is between 15-30 m/s.)
Then you can demonstrate a standing wave just by moving the end up and down by your hand with the right frequency. The wavelength λ is now 10 m (for the basic frequency when there is no node between the ends). Measuring period of these standing waves we can check that the velocity $v = \lambda f$ is the same for standing waves as it was for traveling waves. It is well known that oscillating with the end of the rope with higher frequencies ($2f$, $3f$ etc.) you can demonstrate waves with 1, 2,… nodes – at least qualitatively demonstrating the formula $f = v/\lambda$.
To generate waves with higher frequencies, an electric drill is quite useful. Fix a piece of a thick wire in the chuck and bend it slightly so that it rotates in small circles (with a diameter of about 1 cm) when you switch on the drill. When it touches the rubber rope, it moves it up and down – and you can see a lot of nodes on the rope. By measuring the distance between

the nodes by a ruler you can measure λ and from the known υ determine the frequency *f*. Try this also with a thinner rubber rope and an electric shaver as the oscillator!

4. Activities in Heureka project aimed at teachers

Heureka ("Eureka" in English) is a project that started and developed "from bottom up", from the ideas and efforts of a few teachers nearly 14 years ago. What is interesting is the fact that it not only still lives but develops further and attracts more teachers than before.
Heureka is oriented to both pupils and physics teachers. Here we will look closer at the "teachers' side" of the project. (Its "pupils' face" was shortly described in [2].) We need not to be too detailed here – if interested, see web pages [6] where you can find basic information on the project. (There are several English pages there and, of course, many more in Czech, but with photographs illustrating the atmosphere of our seminars.)
For many years Heureka was nearly private activity of just a few people, with no official support. Then, some 5 years ago, further people started to be involved, the cooperation with the Department of Physics Education became closer and things began to accelerate.
Now there are about 80 people actively participating at the project: students, physics teachers, several university teachers and some other people. (This is in spite of the fact that teachers do *not* obtain any official certificate for training in the Heureka seminars, they came quite voluntarily, sleep at weekend seminars in their sleeping bags in classes etc. – you see this is really very informal training!) The project became quite known and is also (since 2003) supported by grants of the Ministry of Education of Czech Republic. And what is more important – it really lives! Just, for example, look at the activities in 2004:

- 3 common weekend seminars for "traditional participants" + 3 regional seminars for these participants,
- 4 weekend seminars for "new participants" (these seminars form two-years course),
- 3 special weekend seminars (one of them in Bratislava, Slovak Republic),
- regular seminars for students (future teachers),
- 1 bus trip to laboratories DESY (Hamburg), "House of Science" (Stockholm) and "Experimentarium" (Copenhagen),
- 1 annual conference (not very traditional; it had the form of a series of workshops) with more than 50 participants.

At the conference we had already one guest from UK, see "report" [7]. In 2005 we published proceedings [8] from conferences in 2003 and 2004 and invited one guest from the Netherlands and one from Slovenia. (We do not expect such exponential growth will continue endlessly. :-) Now in November 2005 we will present Heureka on the European festival *Science On Stage*.
Taking it all together, it is perhaps not so bad for a project started as an initiative of a few teachers. But we still feel to be rather closer to the beginning than to the end of the road…

■ What can …: Fourth example

To give an idea of the possible content and character of workshops at Heureka "annual conference" I would like to present very shortly the workshop I lead in 2004. Its title was "*Don't be afraid of soldering*".
The aim was to enable people to train working with a (transformer) soldering iron. But just to solder wires together would be boring. So I came to the idea that everybody may make a simple tester with just a battery, 2 LEDs and one resistor (see the scheme at Fig.4). Despite of the simplicity, it appeared that one can use the tester for more than 15 simple tests and experiments.

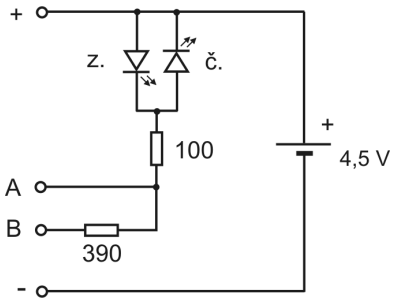

Fig. 4: Scheme of a simple tester

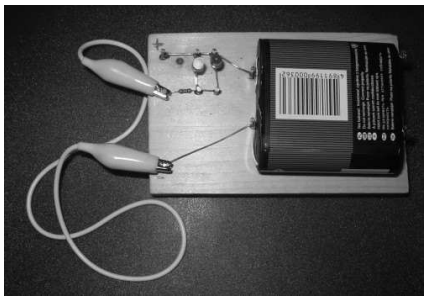

Fig. 5: The tester

The construction of the tester was quite simple (see Fig.5): wooden plate and small brass nails as soldering points. It appeared that everybody from 40 participants who went through the workshop managed to build the tester in time and to try a few experiments with it – even people who said they were holding soldering iron maybe for the first time in their lives. (The workshop lasted 1,5 hour, maximum number of participants was 10, the workshop was repeated four times.) At the end the participants took their products proudly away.
Of course, for some participants soldering was nothing new. These people could build a bit more complicated version of a tester which included one transistor and enabled some further experiments.

5. Further impacts?

The natural question now could be: Are these activities still not too limited? Have they any further impact?
It has to be said that they are not isolated. Three other activities, in some sense more far-reaching, may be mentioned:

- *Fair of Inventions of Physics Teachers*. It is an annual conference of Czech physics teachers from all types of schools. These conferences started in 1996 and are oriented mainly to school experiments. They take place in Prague (typically every second year) and in other towns (Plzeň, Příbram, Olomouc, Brno). The number of participants typically exceeds 150. These conferences provide a nice opportunity to present new ideas, results of some projects (even projects from summer math-phys camp) etc. See for example English web page [9]. Apart from normal proceedings printed each year we published in 2005 an "electronic superproceedings" [10] with 226 selected contributions from first nine years of this event plus 12 "extended articles" and other materials.
- Web server *Fyzweb* [11] aimed at students, physics teachers and at any people interested in physics in Czech Republic. This server started several years ago as a part of a Ph.D. work. Now it runs mainly due to work of students and Ph.D. students of our faculty. To describe it would require writing a special article. Here we could just mention that Fyzweb is now quite well known and used by both physics teachers and students.
- We also participate at some activities aimed at "general public". This year we presented simple physics experiments at a special exhibition "Science at the streets", which took place at various parts of Prague for two days in June 2005. (By coincidence just at this very month our department moved to another building… In these circumstances the help of our students, future physics teachers, proved to be extremely vital before as well as

during and after the presentation.) Some photographs illustrating the atmosphere may be found in the article [12].

■ What …: Fifth example (the last one)

There is a little space left for description of some more experiments. Let's finish with just one experiment from a bit funny series "Happy Cow physics". In this series I use a *really* very simple tool – small round box for cheese. Initially I meant this idea as a joke and as a slight challenge to "invent" physics experiments with such a tool. Then I was surprised that it is possible to think out more that 15 experiments – and that other people (e.g. at the conference [9]) seem to like at least some of them.
The example I chose is a *centrifuge*. The axis is made from a skewer, as a motor we use a small electric drill for modelers. The frequency of its rotation may be quite high: more than 100 Hz or even more. (Manual says it could be up to 18000 rpm but I have never tried for the "cheese box centrifuge" more than half of it, i.e. about 150 Hz.)

Fig. 6: A centrifuge

Fig. 7: A centrifuge at work

A natural object to put into our centrifuge is a piece of cheese. (It is sufficiently soft to demonstrate the deformation.) We should put there two pieces to maintain the balance. After few moments in the centrifuge the cheese will spread to a thin layer.
Warning: Cover the cheese box well. Otherwise the cheese will spread everywhere… And be careful not to put into the centrifuge anything hard or heavy – the forces and accelerations are not small!

In fact, this is just what is interesting at our centrifuge: the acceleration. At the frequency of rotation of 100 Hz the resulting acceleration exceeds 20 000 m/s^2, so it is two thousand times greater than normal gravity acceleration! Of course, this results from a simple very well known formula – but the resulting number may be surprising perhaps not only for pupils… That's why one must be careful: 5 grams of cheese push the cheese box wall by the same force as normally 10 kg weight pushes the ground. And the force increases with square of the frequency.
Such discussions may turn the "gray theoretical formula" $F = mr\omega^2$ to something vivid, interesting and applicable. Then you can discuss for example the forces acting on rotating CDs' etc. etc.

6. Conclusions: why?

I began this article with answering questions like "Where?", "When?" and "What?". One important question remains: "Why?". Why we do it all?
A sincere answer is very simple: Because *we like it*.
But, of course, there are more reasons than just our pleasure. The important point is that *the participants* (students, teachers etc.) *like it*, too. We know it from both formal and informal questionnaires and other forms of feedback, we can feel it very intensively during the activities and we are also assured by the fact that the participants come back on further occasions.
The other reason is that *it seems to work*. Many activities described above really motivate people, help to destroy barriers in our understanding and between us, move things further and enable all of us to evolve. It may be interesting to check such (rather vague) statements by some formal research. Up to now, they are more or less verified by practice and by the life itself. Maybe that "verified" is too strong a word in this context. But our experience is encouraging. At least for us they are encouraging enough to push us to go on.
There is also the other side of the question "why". Why to bother with it you, the reader?
For us it is clear. We try to be open and we think that exchange of ideas and experiences is both important and exciting. That's why we look for new contacts with people "tuned at similar wavelength".
Let me to address the last question to you, the reader of this article. Have you found some similarities in what you do and what we try to do? And do you think some mutual inspiration might be fruitful? If yes, let us know. To exchange ideas and experiences may be really both useful and exciting…

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