# What defines a success in lectures and labs? Case studies in Physics teaching

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## Abstract

The article describes successful results attained in teaching by a few people with miscellaneous viewpoints, by different means, various methods and in varied Physics teaching fields. A success has a different dimension for each of them. Four cases are discussed. More details can be found in the article.

**Keywords**: Teaching by observations and discovering; Teaching by developing; Teaching by involvement.

## Summary

The individual results of mastering the teaching are convergent with PTEE hot topics. A coincidence?

## Introduction

Authors of this article have over thirty year experience in teaching, except the last, young author. Such a long period must have provided findings and conclusions on what could define a success in teaching. Sharing these findings and considerations with others may be inspiring for a young generation of academic teachers.

## Case study N°.1. Involvement of students to innovative thinking, even beyond the Physics.

Prof. Wlodzimierz Salejda lectures on Introductory Physics for Bio-Engineering students and Environment Engineering students (the first year of study). First-year students came to the university with various scores from secondary schools (a full range: from excellent pupils to very poor ones with much to make up and learn). The original idea how to activate students to learn more than a minimum level rose not so long ago. The idea is that students are expected to become mini-experts in a certain field. It does not relieve students of not learning the other parts of material. Being an expert is important and ennobling. Students discuss their original thoughts and dispute any doubts (with a lecturer and with themselves). They have innovative ideas and interesting looks (sometimes a little wrong) while reading physics books and publications. They feel they are responsible for understanding and knowing this particular single physics problem. This is a challenge for them. How do students prove they became an expert? They write an essay. Exemplary essay themes: “Physical properties of solid state matter to be used in energy conversion” or “Physical properties of optical fibres applied in optical communications”. The topics are selected to cover physics peripheries, focussed on technical applications and engineering solutions. No-one wants to be a bad expert (a psychological trick), so students do their best to learn much on their theme. Generally the essays are good and very good. But more important thing is that a student is convinced that being a mini- expert (1) is possible, (2) is available after some finite work, (3) can be extended to other fields (such as mathematics or waste recycling etc.). This helps first-year students to start learning more effectively (than they would do before), to start thinking (in a scientific way) which should not stop after the physics course. What is a measurable merit of Case N°. 1? Physics examination results. After the essays were introduced (with all their requirements and consequences) 80% of students passed the Physics examination while before only 50%. The success consists in showing a student at the beginning how to individually gain a small part of knowledge by himself in order to let him or her extend this accomplishment farther. And to show that one’s thinking pays. A huge knowledge mountain raised in front of the first-year student can be reached in small successful steps only.

## Case study N°.2. Modifying versus creating.

What has become more effective?

Assoc. Prof. Beata Radojewska teaches Computer modelling and simulations of phenomena (various years of study). It has two parts: proficient programming in a computer language and deep understanding of the simulated phenomenon. These two halves most frequently are unbalanced. Just by chance it happened once that for a level compensation the background models had been given to students prior to their laboratory to establish standards to start up. The majority developed a task unexpectedly well and quickly (by an extension of the given model). So it became a routine: a background complete model and a more difficult task to solve on its basis.

Let me describe an example: a simulation of waves.

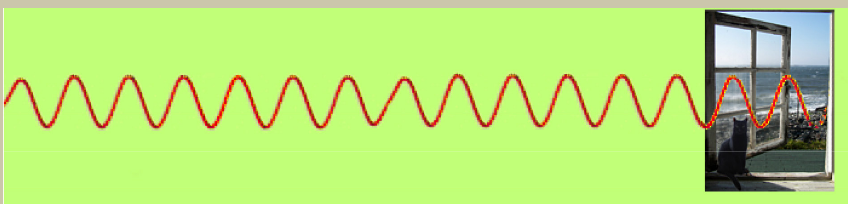

Fig. 1. One-dimensional transverse endless wave. Worked-out model to start modifications.

A model of the one-dimensional transverse wave (as in Fig.1) can be described by the equation:

$$\frac{\partial^2 U(x,t)}{\partial x^2} - \frac{1}{c^2}\,\frac{\partial^2 U(x,t)}{\partial t} = 0 \qquad \text{with } U \text{ – the oscilation, } c \text{ – the velocity} \qquad (1)$$

After converting the equation to a conjugate system of first-order differential equations:

$$\frac{\partial V(x,t)}{\partial t} = c\,\frac{\partial K(x,t)}{\partial x} \qquad \frac{\partial K(x,t)}{\partial t} = c\,\frac{\partial V(x,t)}{\partial x} \qquad (2a, 2b)$$

$$K(x,t) = c\,\frac{\partial U(x,t)}{\partial x} \qquad V(x,t) = \frac{\partial U(x,t)}{\partial t} \qquad (2c, 2d)$$

and by discretizing the equations with the numerical differentiation (4$^{th}$ order Runge-Kutta method), and imposing boundary conditions with initial conditions, a set of U( xi , tj ) is obtained in a computer program. Students got the ready code. Then they knew what happened with a phase when the wave was not endless (two cases: a fixed end and a loose end of a wire rope, Fig.2). Students have to write

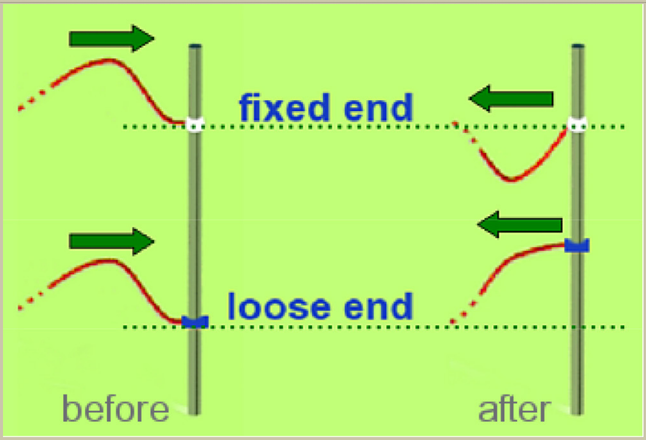


Fig. 2. A wave phase behaviour at the rope end for two case: a fixed end and a loose end.

a code which models U( xi , tj ) for the two cases, assuming the wire rope length as L. This requires an extra insert to the existing code, not difficult, but without understanding the wave propagation, doing this is impossible. Advantages of the approach are numerous:

- faster teaching, not wasting time for basics (a basic solution is ready to use and given to students);
- wider range and higher level of knowledge reached by students this way;
- a real proof of good physics understanding and sufficient proficiency in programming;
- (when the task is done);
- greater involvement of students to the tasks (students blush ashamed when they cannot modify a ready simple thing, so they spend more efforts to learn in order to show they can complete the task).

If the students had been asked to create the final task from the zero level, they would not have completed the task in time or not at all. Starting from a certain level (given to them) and modifying the ready solution is more effective. Many years of employing this method confirmed the thesis that in Modifying versus Creation the Modifying won. There is a minor disadvantage: extra time spent to prepare ready to use examples. I use this method to all my courses, even database programming. Another side of the approach is to provide students with more fun to play with Physics. Here is one of examples how to make laboratories more attractive. A ready solution is: an analysis of vector forces acting on a skier (or snowboarder) in a quarter-pipe with a constant friction coefficient and a constant radius of the pipe (Fig.3). The slope changes with a position and a centrifugal force also acts. Students got a ready to use code giving a force map (with time and position).

The task this time was more surprising. They watched a video http://radojewska.net/ptee2014/ski/

and had to recognize and discuss forces acting on a skier (many rotations and a fall at the end), Fig.4.

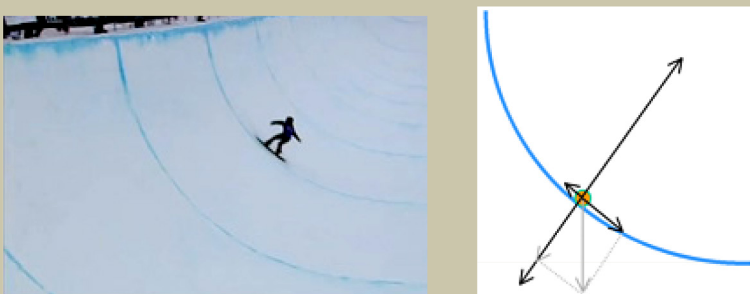

Fig. 3. A snowboarder in a quarter-pipe with a constant friction coefficient and a constant pipe radius (in the left) and the vector force diagram of gravity, friction, reaction and centrifugal forces (in the right).

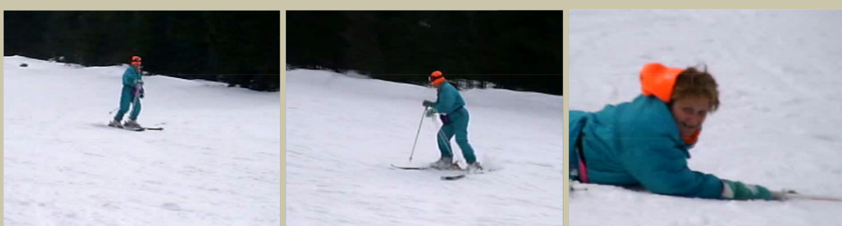

Fig. 4. Frame shots from a video with a skier making evolutions on snow (http://radojewska.net/ptee2014/ski/). A task is to analyse qualitatively forces acting on the skier at every stage.

After the students realized that a skier was their teacher, a discussion became more vivid, more excited and lively, interrupted with funny comments and laughter. Everyone wanted to add his/her considerations in this brainstorming. And it was only a video which activated the students. A success consisted in a video choice.

## Case study N°.3. Observations of the indivisible physics, not divided into handbook volumes.

Dr Jan Szatkowski lectures on Introductory Physics for Electronics students and Photonics students (the first year of study). A level of physics teaching in secondary schools is rather low. So the main burden of this falls on the first year of studies. Handbooks are to bridge a lecture. Most often the handbooks are published in volumes or arranged in specific chapters (Mechanics, Vibrations, Waves, Electricity etc.). But the surrounding world is not ordered this way, is completely intermingled. So lectures should follow such a perception to ease understanding of the surrounding world. The discussed problems should tie many physics chapters. It is even more important in case of physics demonstrations. The demonstration presented in a lecture must be simple (without black boxes), must show basic principles, must help students to explain observed phenomena and preferably must relate to more than one phenomenon. An explanation should not accompany the demonstration, only questions: what happens. Students by themselves should reach a correct model and principle through closer and closer approximations and findings. If they propose a wrong guess, a lecturer should guide to a correct one by disclosing questions, and not by negation. Students must find their fallacy themselves. This method can learn thinking through a critical analysis, can consolidate a uniform model of the surrounding world.

Charging an electroscope with an electrized stick and discharging with a flame is one of good examples of the mentioned demonstrations. Why does a friction charge a dielectric stick? How does the charge fill an electroscope? Why does hot air discharge the electroscope? The demonstration phases are shown in Fig. 5. The movie is also available: http://radojewska.net/ptee2014/electro/

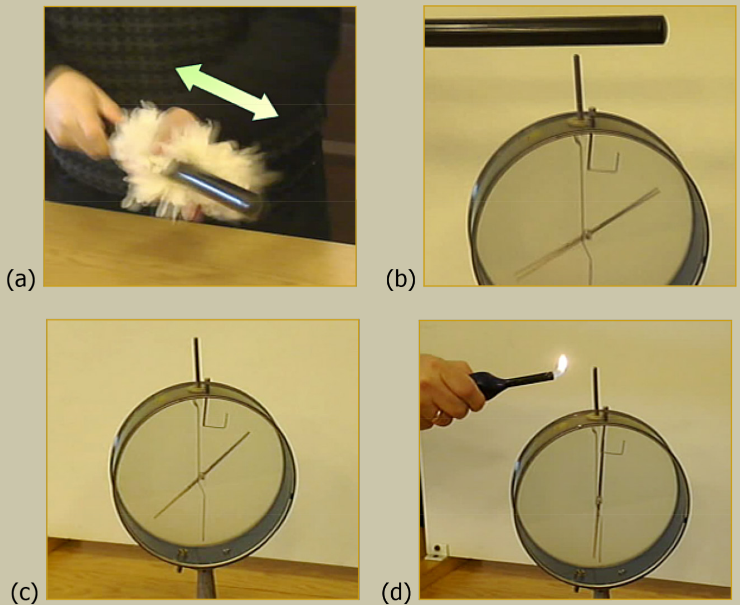


Fig. 5. Distinguishing phases of the demonstration: (a) a stick electrization, (b) charging an electroscope, (c) the electroscope charged, (d) discharging the electroscope with a flame.

It is not easy for students to explain all phases at the beginning. They need to combine many branches of physics at the moment. And this was the aim of the demonstration. Specific problem- oriented teaching like this one can develop complete thinking, can accustom students to seeing more than a single page in a handbook, can learn how to solve any future engineering complex problems. The success consists in a teaching of combined problems with many phenomena involved which usually occur at the same time or in a typical sequence, to show that physics is indivisible, just like the surrounding world, just like a future engineer's job.

## Case study N°.4. Experiments which can show a beauty of the Nature, a cleverness of Physics and satisfaction of an educator

Prof. Ryszard Poprawski lectures on Dielectric Physics for Technical Physics Engineering students and Dr Agnieszka Cizman teaches in Solid State Physics Laboratory. No doubt that experimental physics is a necessary part of Physics teaching. There are physics laboratories at many, maybe all universities. Why is one experiment in such a lab better than other? The experiment should explain a physical mechanism of the phenomenon. The experiment should be related to phenomena applied in technology. The experiment should show future prospects and possible developments. The experimental set-up should not be expensive (taking care of the university budget). Looking for and finding such a kind of student experiments were the aim of Dielectric Physics Laboratory team. The team can point the most brilliant set-ups built (by the team) and used in the laboratory, for example: Set-up for temperature studies of the spontaneous birefringence in crystals (a diagram is shown in Fig.6). The set-up story reached only 2005. Ryszard Poprawski was a supervisor of Agnieszka Cizman's master's thesis on the set-up to be made within own (institute) capacity. A whole design was passed to Mechanical Workshops in Institute of Physics, to Mr Edward Ciupidro. All parts, made there, were then mounted and tested at our laboratory. Triglycine sulfate crystals, grown also at our laboratory, were used for tests, due to their ferroelectric properties with the second-order phase transition at 49°C. The crystals are centrosymmetric in paraelectric phase, so the anomalous part of the spontaneous birefringence possesses a character of the spontaneous Kerr effect.

The set-up tests were successful (see Fig. 7). After the entire undertaking had been described in an article [Cizman *et al.* 2005], it brought an interest of Polish universities. After a few improvements the set-up was reproduced and sold to several universities. It is also an economical dimension of the venture.

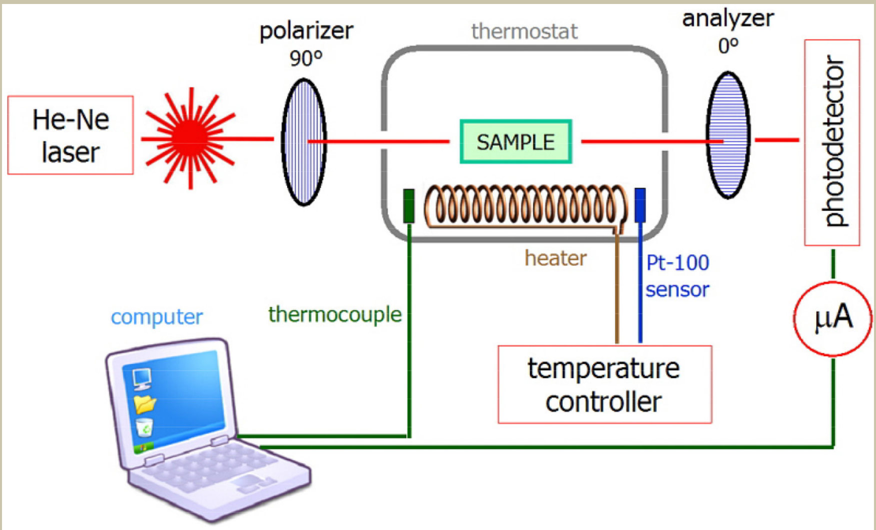


Fig. 6. Schematic set-up diagram for temperature-birefringence measurements.

The set-up is not only used in a teaching process, but successfully in physics research as well [Cizman *et al.* 2006, Cizman *et al.* 2007]. Due to this experimental set-up our students can learn optics of anisotropic media and ferroelectric phase transition mechanisms. The birefringence phenomenon is an important point in students engineering education due to its technical and medical application such as medical diagnostics and imaging, seismology tests, mechanical stress analyses, also widely used in mineralogy and fiber optics.

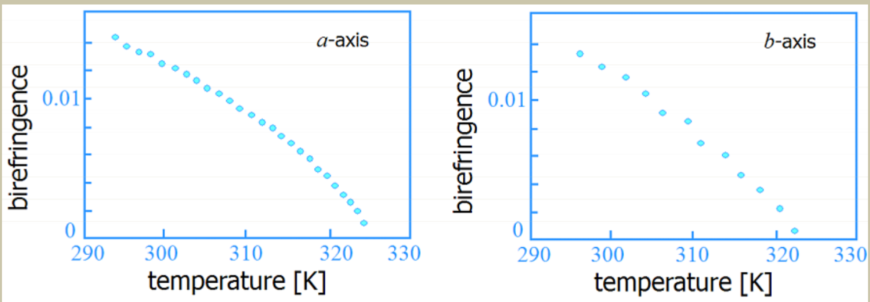


Fig. 7. Temperature dependence of the linear birefringence changes for triglycine sulfate crystals along the a-axis (in the left) and along the b-axis (in the right) [Cizman et al. 2005].

The measurements were carried out with a set-up shown in Fig. 6.

Our success consists in a contriving of an interesting experimental set-up, in producing a prototype and in profitable selling the set-up to other universities, and most important of all: in an enrichment of teaching infrastructure and research means. It is worth mentioning that on a basis of a bilateral exchange agreement between our university and Université de Strasbourg the French students have ability to study birefringence in our laboratory on their stay in Wroclaw.

## Final remarks

A success in teaching has many dimensions and many faces. And after all it gives a great teacher's satisfaction.

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