Electricity and magnetism step by step and optics step by step: optional special labs in first years of pre-service teacher training

Irena Dvořáková, Leoš Dvořák

Department of Physics Education, Faculty of Mathematics and Physics, Charles University, Prague, Czech Republic

Abstract. Introductory physics courses for future physics teachers serve various, often quite “divergent” purposes. On one hand, they should present physics at university level, using mathematical tools like integrals, differential equations, tensors etc. with sufficient degree of exactness. On the other hand, they should develop conceptual understanding, physics insight and “intuition”, skills necessary for doing experiments etc. Often, the development of such conceptual understanding and necessary skills is aimed also “at university level”, assuming that students know the basics from secondary schools and have some experience with at least elementary experiments. Moreover, it is often assumed that students themselves will see the link between “secondary school physics” and “university physics”. However, often this is not the case and future teachers complain that there is a large gap between physics at those two stages. To help students reduce this gap we created two optional seminars: Electricity and magnetism step by step and Optics step by step. These seminars give students better understanding of physical concepts as well as some basic methodical comments for their future work with pupils. Both seminars are based on the methodology of the Heureka Project (Dvorakova 2013a). In this article we would like to present our experience with both seminars.

1. Introduction

Our students – future physics teachers – have special physics lectures since the first year of their university studies. In the second semester there is a lecture (and seminar) on Electricity and magnetism. Students learn “the university physics” here, calculate different problems, etc. However, (about ten years ago) we found that students are able to successfully pass exams from this topic, but they have problems with very elementary tasks – to light up a bulb only with a battery, to connect parallel circuit etc. This was the main impulse which initiated a new seminar Electricity and magnetism step by step. The second seminar was opened two years later at students’ request, because they considered a “step by step” seminar as very useful also in Optics.

2. Main goals of the seminars

Main goals the seminars should fulfil naturally follow from problems mentioned above. In general, students should there:

- build bridges between “university physics” and physics taught in junior and senior secondary schools in their minds and/or make such bridges stronger
- experience teaching and learning physics that is strongly based on simple experiments they do by themselves.

Of course, these two goals are interconnected: students should learn how simple experiments relate to relevant physics theory and should be able to illustrate such relations.
Moreover, seminars also give students a very good opportunity to become explicitly aware of some important misconceptions in the discussed topics by experiencing the misconceptions by themselves or by their colleagues.

Last but not least, each seminar is also a place where students improve their practical skills concerning simple experiments and, of course, some other more general skills and competencies: to collaborate, to discuss, to present results etc.

3. Basic characteristics of the seminars

As we already mentioned, both seminars are organized simultaneously with usual university lectures. They take 2 hours per week, in the 2nd and 3rd semester. Although the seminars are voluntary, almost all students on adequate level attend them.

At the beginning of both seminars students are asked to solve several problems from basic school physics. They find that they have problems with this test; usually none of them are able to solve all tasks without mistakes. We know that students have many “empty places” in their minds, but because each of them has different “empty places”, it has no sense to try only refilling missing knowledge. It is necessary to build concepts from beginning. That is why we start all topics from the basic level. Sometimes we say that no previous knowledge is expected (after the introductory test, of course).

Students work similarly to children at basic school. They do experiments, discuss, and solve different problems. Some examples of these problems will be presented later.

There are two more important parts of the program of seminars. One of them includes didactical elements and methodical comments for students’ future teaching at school. In spite of the fact, that students have about four years of studying ahead of them and they usually have little idea about their future work with pupils, we consider those comments as very important. We are convinced that the sooner students gain a positive attitude to teaching the better. The second important part of the seminars is continuous interconnecting the basic level of physics with the university level.

The seminar *Electricity and magnetism step by step* includes four main topics – magnetism (permanent magnets and their field, magnetic field of the Earth), electrostatics (properties of the charge, electrical conductivity and electrostatic induction), electric circuits and electromagnetism (magnetic field of the wire and coil, mutual influence of a magnet and a conductor with current, electromagnetic induction). In the seminar *Optics step by step* we start with the basic properties of light, shadows and colours. Then students investigate mirrors (plane, concave and convex) and lenses. They study refraction of light, too. The last part of the seminar is focused on wave properties of light (diffraction, polarization, etc.).

**Example 1 – Several tasks from the introductory tests**

- Design and describe an experiment which shows that there are two types of electric charge. You can use a plastic rod, a container with a leaf of aluminum foil, insulation pad, and fur.
- Solve and give reasons for your decision: How does the ammeter reading change when the switch is closed?

![Diagram](image)

- Add two switches (plus wires if necessary) to the circuit so that their different combinations will cause 1, 2, 3, or 4 bulbs glow.
• Point A lies on an optical axis of a magnifying lens (not between the lens and its focus point). Find geometrically the image of the point A.
• Using magnifying lens we project a flame of a candle on the screen. Describe what you will see if we cover the top half of the lens.

Example 2 – Electric circuits
The results from different research studies show that students need more opportunities to work with real electric circuits. Students have problems with understanding and correctly applying the concept of a complete circuit. They also need to understand multiple representations of the circuit to deeply understand its behaviour, (e.g. Osborn 1983, McDermott & Shaffer 1992). Therefore we spent several hours going through the whole methodological sequence, which helps students to build the concept of electric circuits using multiple representations. This sequence was described in details in Dvorakova (2013b).

In this text we present only the starting part of the sequence:

| Step | Activity |
|------|----------|
| 1. | Play with a small bulb and a battery, connect bulb to a battery (use a piece of wire if necessary) and try to make it glow (Exp. 1). |
| 2. | Draw a picture which describes the arrangement of your experiment. |
| 3. | Connect the bulb to the battery through as many things as possible at the same time so that it glows (work in pairs) (Exp. 2). |
| 4. | Sketch how the experiment looked (using 4 – 5 pieces is enough). Describe the common properties of things you used in the Exp. 2. |
5. Draw different situations, where the bulb is connected to the battery, yet it does not shine (crazy ideas).

6. Teacher shows circuit diagrams to represent circuits. Teacher shows tables for describing the state of switches and bulbs.

7. Students work with real bulbs, switches and batteries and build assigned circuits.

**Fig. 1.** First activities from the methodological sequence Electric circuits

We would like to bring your attention to step 3. This competition proved to be a very interesting activity and students like it very much. Furthermore it gives a lot of possibilities for further conclusions.

**Example 3 – outdoor activities**
One of the very favourite activities is outdoor playing with mirrors and lenses. We need a day when the sun in willing to play with us.

Students do a set of experiments, for example:
- Reflect the sunlight to the given place using one plane mirror.
- Reflect the sunlight to the given place using two plane mirrors.
- Light up a piece of paper using a concave mirror.
- Light up a piece of paper using a magnifying lens.

**Fig. 2.** Outdoor activity during the seminar *Optics step by step*
4. More than mosaic of experiments
Examples presented above could possibly raise an impression that the core of the seminars is just a “mosaic” of simple experiments, perhaps loosely connected with parts of theory. However, they are much more than that. In fact, looking from a broader view, they serve also as classes preparing students for their future teaching career.

Structure of the seminars follows the way how these topics are taught at junior secondary level by one of authors – so students are, partly “implicitly” and partly openly, being prepared for teaching of these topics. This “horizontal structure” of the seminars is supplemented by “vertical connections” to formulas, quantities and theory students learn in university lectures. (As it was mentioned, the lectures are taught in the same semester as the “step by step” seminars.)

The very important aspect of the seminars concerns the fact that learning students experience there is inquiry-based. (It is not completely free inquiry, the role of a teacher is important there but it is definitely far from any cookbook approach.) Of course, the inquiry involves discussion of students and students groups, their collaboration, presenting results to colleagues etc. Therefore, later in their teaching carriers, students can use methods they experienced there as “templates” in their own teaching.

5. Feedback from students
Though no formal tests or quantitative surveys were done at the end of seminars, various forms of feedback from students show that the seminars fulfil the needs expressed by goals mentioned above.

First, in spite of the fact that the seminars are optional, they are attended by nearly all students (future physics teachers). Students of older classes recommend the seminars to their younger colleagues as really useful. At more formal level, such attitude is proved by a survey our Faculty does at the end of each semester among students. (In last few semesters the results of the survey are used to choose and acknowledge “best educators” of the Faculty – and the ratings of our seminars reached that level.)

Apart from quantitative evaluation some opinions of students they wrote in the survey can illustrate the impact of seminars. Let’s present here just a few examples of student’s views:

I think that this seminar prepares us very well for our future teaching career. I appreciate that we solve all problems at the level of students of junior secondary school, to be able to explain them physics in their own words.

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The style of teaching was very inspiring. ... It forced us to think.

I surely recommend it to clarify one’s knowledge. We did a lot of experiments and tried to explain them.

Very good seminar from optics, it really makes sense. It is good to connect optics from lectures with physical “playing” with lenses, prisms etc., seminars are supplemented by thinking about interesting phenomena and instruments. ... anyway, the seminar is an excellent choice.

Apart from these views expressed several weeks after the end of each seminar there is also a long-lasting effect. In classes aimed at physics teaching which take place about two years after the seminars, students repeatedly use what they learned in the seminars and explicitly refer to them.

Based on all this feedback, though mostly qualitative one, we think we can state the seminars really fulfil the needs that forced us to create them.

6. Conclusions
It is hopefully not necessary to describe detailed structure of the seminars here. (To really go into details would make this text much longer.) We think that every educator can adapt the content to their own needs. It is the main approach which is important.

In case you think about creating similar seminars or you have been organizing them already and you are willing to share experience, you can contact us for further details.
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