A computer based physics tutorial for simultaneous use at the university and at secondary schools

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abstract

We have developed a Computer based tutorial in physics which addresses to the bachelor students in natural and applied sciences. It accounts for the growing deficiencies of the incoming students in basic mathematics and physics. The method of presenting the physical concepts in form of lectures and training in form of the laboratory experiments in a successive way turns out to be more and more inefficient. There is a need of additional interactive methods enabling the student to progress at their own speed in a self controlled way. The aim of our tutorial is to underlay the presentation of theoretical concepts with individual experiments. Thus combining the methods of e-teaching with computer based experimentation. It takes place during the second semester thus preceding the conventional laboratory work. After a short theoretical introduction to the subject the student performs his own experiments. There are numerous sensors at his disposition. The readout and. the subsequent interpretation of the data is done online.The tutorial has been successfully tested for several years encouraging us to modify it for a later use at secondary schools.

We present to you the outline of a recently developed computer based tutorial which is intended to bridge the gap between the theoretical knowledge taught in the lectures and the experimental skills demanded during the practical lab work. Although many experiments are performed during the lectures there is not enough time to explain them in detail; thus the students experience them more or less as an illustration to the theory or simply as an opportunity to relax. During the lab work, on the other hand, the inexperienced students stick too close to the methodical problems and the imponderabilities of the apparatus to see the link to the theory. Theory and Practice often seem to be two things which hardly match. It takes a long time for the students to reconcile them – even too long sometimes – so that a lot of students give up trying.

It is the aim of our computer based tutorial to make the complex interplay more transparent which acts between the observation, the modelling and the conclusive experiment which leads to the final theory. It takes place parallel to the lectures in fundamental physics – thus preceding the classical lab work for beginners. The “random observation” is made with the aid of video clips whose frame sequence may be video analyzed to get a first idea of the functional behaviour of the process under observation. The first supposition may be verified by an appropriate curve fitting to the data. The presumed context will be explained within a simple model, which has already been presented during the lectures and which is briefly summarized in the tutorial. In the framework of this model the free parameters of the mathematical functions get a physical meaning. Their behaviour is studied either in subsequent experiments or in computer simulations.

The performance of the experiments and the interpretation of their data are only possible with a certain understanding of the underlying physics. To control it a lot of multiple choice

questions are incorporated. The access to the experiments may thus be allowed only after a given number have been correctly answered.

Learning how to do experiments on their own and to overcome the eventual problems is a very important phase in the student's process of acquiring physical knowledge. Thus emphasis is placed on the formulation of expectations and the subsequent comparison with the measured data, which are subject to systematic and statistical errors. There is a special chapter devoted to statistical distributions and to the treatment of experimental errors as well as to the problem of data fitting by the regression method.
The tutorial has been conceived for our new bachelor in applied science at the University of Wuppertal. The idea is to study two different major subjects in parallel with the same volume of credits without neglecting, however, a more general education in mathematics and information technologies.

The fundamental physics course follows the classical lines of teaching. It embraces the topics:

- Mechanics
- Thermodynamics
- Electricity
- Magnetism
- General wave phenomena
- Optics
- Basic ideas on the structure of matter

It is accompanied by additional forms of presentation with their own specific foci: the exercises to train the skills in problem solving, the practical lab work to learn autonomous experimenting and the computer based tutorial as a preparation to the latter. Attendance is presently on a facultative basis but it will be made obligatory in the near future.

The tutorial is conceived as an electronic book, which has been developed with the author ware program package Toolbook Instructor from the enterprise Asymetrix. It makes use of the following elements:

- **Computer simulations**: they have been written in the open script language of Toolbook and with the animation function of Mathcad.
- **Computer based real time experiments**: they are done with the standard equipment of the practical lab work for beginners. For data acquisition a special interface with a set of various sensors is needed. We use the ULI System from the American enterprise Vernier. The read out is done with the program Logger Pro.
- **Cuve fitting:** LoggerPro also allows curve fitting to the data, but most of the final evaluations of the data has been done with the mathematical program package Mathcad
- **Video experiments.** There exists also an option of Logger Pro to analyse video clips. To do this, the Quick-Time player is needed.

The tutorial is organized in form of a set of independent chapters. The actual topics are:

- Experimental error treatment and curve fitting
- Linear motion
- Rotational motion

- Simple mechanical oscillations
- Simple electrical oscillations
- Coupled oscillations
- Superposition of waves
- Diffraction phenomena

Further Chapters are intended:

- (Fourier analysis)
- (Propagation of waves)

Most parts of the tutorial are already running for three years. The results, however, are not yet conclusive. The reasons are manifold:

- The status of the programs and their interplay are not yet stable. Thus the tutorial in its experimental parts is still far from being self supporting.
- It is difficult to find experienced supervisors.
- The computers and the software must be maintained steadily.
- Students have to learn the systematic use of the computer as an instrument and not as a toy.
- The student's behaviour is very diverse when they have to face unexpected problems with the computer. Some of them accept the challenge others have a very low threshold of frustration. In both cases the intention of the tutorial tends to fail: namely to transport a physical content.

In spite of these initial difficulties, the evaluations by the students have been quite positive. The students in physics have been delighted by the modern presentation of their discipline. They appreciated especially the immediate display of the experimental results leaving enough space for trying out ideas of their own. They also confirmed a better understanding of the experiments and the associated physics. All in all, the atmosphere during the sessions was attentive and stimulating. But the sessions took place between the terms. The judgement of the students in chemistry was more ambiguous. They all stressed the modern form of teaching as stimulating their interest but only part of them attested a better understanding. This is not very surprising considering the fact that the sessions took place during the term and that only a fraction of the students attended the lectures.

To conclude: This electronic teaching tool is certainly not a cure-all for the different deficiencies of our students, but it helps to motivate them. It acts more like an amplifier: it does not create the signal but it may amplify one when it is present. To detect these signals is a permanent challenge. This is the reason why my colleague Prof. Fischbach has launched the initiative SCHULPOOL to promote the pupil's experiment at school. He will report on it this afternoon. We are studying in which way the experiences with the present tutorial may be transferred to the computer based experiments at school. In case of a positive result we will report on it at a future conference.