Computers and modelling at SCHOLA LUDUS teaching of physics

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Abstract

The SCHOLA LUDUS approach for using computers is presented. The emphasis is on physical modelling, physical process simulations and development of student critical thinking. Students observations and experiences should result in their own descriptions and further predictions, models, graphs, etc. . Hence, the computer is only a necessary complement that should be used after all of these, at the right time with respect to the students readiness, including their skills and knowledge of necessary concepts and theories, to make the knowledge more intensive and operational and, at the same time, to make the advantage of computer usage more clear and convincing. Concrete examples are referenced.

Introduction

Starting with SCHOLA LUDUS projects for out-off-school activities, mainly in the field of physics [1], there has been developed a non-formal science education approach for alternative school education. The approach is based on three complementary pillars [2]: 1. The complexity process. All processes are considered as complex. For teaching simple experiments and *the method of recognition the phases of the process development* are used . 2. Parallel cases. Parallel method based on the SCHOLA LUDUS axiom that parallel study of cases (experiments, graphs etc.) lead to better understanding of the non-linearity of real processes and to non-linear dynamic thinking. 3. The authentic learning. This includes constructivism *and three strategies – spontaneous play, directed play and big creation play*. What is the role of computer in this frame?

We use computers first of all, to 1. for collecting and elaborating data from real experiments and controlling the real processes, 2. to see the influence of different parameters of a phenomenon, and 3. for modelling and simulating physical processes. But before making use of computer, a lot of simple real and/or thought experiments should be provided by the students themselves. Here study at extreme parameters helps to gain inside into the process [3]. Students´ observations and experiences should result in their own descriptions and further predictions, models, graphs, etc. [4,5]. Hence, the computer is only a necessary complement that should be used after all of these, at the right time with respect to the students´ readiness, including their skills and knowledge of necessary concepts and theories, to make the knowledge more intensive and operational and, at the same time, to make the advantage of computer usage more clear and convincing.

1 A numerical model and physical modelling

While “ready” computational systems and models are used in schools, in our work we prefer modelling and simulations by students. Considering macroscopic phenomena, a numerical model consists of few simple equations and conditions. Solutions are given by parallel graphs of different characteristics that are discussed in their relationships.

Students are asked to look for extreme conditions where often the models collapse. Then the boundary of the model validity and its reasons are discussed. There could be a lack of members in the model equations, e.g. there are neglected some phenomena that could play, in fact, a significant role at the supposed region of parameters, or there are insufficient equations, conditions etc.. Then the discussion is, whether we are able to change the model or not. Perhaps we don’t know the correct mathematical expressions, or the particular parameters needed for the right expression are not known, or they are known only very roughly with not sufficient accuracy, or on the other hand, we know them but it would be too complicated to calculate the complete model. It is also possible that the whole conception of the model, or the theories that are (today) at disposal are not sufficient for the problem.

The parallel graphs and different representations allow students to discuss the linearity resp. non-linearity of the problem [4,5]. As different representations there are considered not only different characteristics combinations (one versus other in one graph) but, for example, also characteristics that are normalised by typical values of the physical system [5]. The last enables students to discover the cases of similarity. If time development of a physical process is modelled there are always at least three phases of process development - the beginning phase, the core of the process and the end phase. The students´ standard procedure is to recognize all significant phases; for each particular phase they try to set up a model and the respective starting and boundary conditions. Students find the crucial zones and discuss respective interesting points where the process is changing its behaviour significantly. They try to predict the influence of these zones to the endpoint of the process. Another student task is to discuss the possible changes of the system components in order to make the process more effective, reliable, not risky [5].

Only afterwards, students either prepare the computer programme for numerical solution or they could use a ready programme. The desire, of course, is to obtain the time development of all characteristics during the whole process [6] that allow the students to predict the process development at any parameters. However, in general, we are not able to build up a simple model for all of the phases [5]. Nevertheless, in SCHOLA LUDUS educational approach this is considered as an advantage. It offers the teacher opportunity to open a discussion about real physical problems joined with the case and the possibilities of the process modelling in general. By this, modelling allows students to understand on one hand the limits of our physical knowledge with respect to empirical knowledge (data and their exactness), and on other hand, the limits of the theory. Comparing numerical results with reality shows also the deficiencies of the model used. This leads the students to the very important conclusion that models are only approximations, and the question is "how good is this approximation" with respect to the reality.

2 Simulations at the microscopic level

The numerical solutions for different parameters open a new "quick" view to the processes that sometimes fit the imagination, but often bring surprises. In any case, completed with real experiments, it could be a big fun. And hopefully the students' awakened curiosity can be answered models on the microscopic level. Though it was not mention explicitly, the upper models and modelling were related to macroscopic processes described by macroscopic characteristics and parameters. Complexity requires necessarily also microscopic view. To gain macroscopic phenomenon as a collective result of many small particles we use simulation. At simulation the small particles behave according to some microscopic rules some of which could be supplied by mean values - speed, probability, frequency, typical representative etc. Approaching process by simulation we implicitly consider the inner mechanism of the process.

According to our experience the best way to start simulations is with life models. Students play the role of molecules, photons, electrons etc. [4,7]. The model could be illustrated also by a computer animation of many particles and their many inner steps, mutual interactions or interaction with the system boundaries. But pure picture animation is only an illustration. Only calculations of sums of the interactions´ particular results give quantities that correspond to the macroscopic characteristics of the system. Somewhere here is the moment when students may find the hidden unity of macroscopic and microscopic views of Nature, one of the goals of knowledge, that requires the attractive introduction and comments of a good teacher.

Conclusions

The computer represents advanced technology, and in physics study, we suppose, should be used as a tool for advanced study. By using the computer in their physics lessons, the students gain skills not only for solving problems by computer but also thinking skills that will help them to evaluate problems without computer. They learn how the use of computers could help to understand real processes and, on the other hand, what are the limits of computers and the respective physical theories. Finally, as a besides product (though for physics learning the first), physical models, modelling and simulations deal with practical and theoretical physics, and lead to better understanding of physical concepts, conceptions and theories. The use of computers could accelerate learning of complexity. It supports students´ skill with parallel method and also with authentic learning as the base for lifelong education. But we emphasise that all these are possible only if students have preliminary intensive experiences with real experiments – to join them with the real world.

In this context there is an additional relevant question: Are modelling and simulations really necessary for students in general and are they mentally available for all mentioned above? We suppose, YES. Technology is everywhere. Because of protection of personal and social manipulations, because opening doors for understanding of science and technology in the future. We (all) want to understand the elegant and effective algorithms of the Space and Life. And therefore no effort should be spared in education to get students to understand these things.

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