Computer Aided Learning in Undergraduate Physics Teaching

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FLIP collaboration

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Abstract

To increase the attractiveness and efficiency of physics undergraduate teaching we have implemented the use of computer programs in the learning process in several physics courses. Existing courses have been complemented with computer simulations of physics processes using existing computer programs covering a wide range of physics items. In addition new courses have been designed and implemented exploiting the powerful potential of computer simulation.

Introduction

The introduction of new teaching methods, such as a more systematic use of simulations of physics processes, involves changes in the way physics has been taught and the teaching tools used. Teachers have to get used to a new set of computer programs and the classrooms and lecture halls have to be correctly equipped with computers, display facilities and network connections. The experience of the implementation of Computer Aided Learning in undergraduate physics teaching presented here is based on the work by Stockholm University and Royal Institute of Technology Collaboration, FLIP, Flexible Learning in Physics[1].

FLIP

The aim of the FLIP project is to increase the flexibility and efficiency of physics teaching and to introduce an international character and co-operation into the educational program. This is an

important part of making Swedish students internationally competitive and of making our teaching more attractive to foreign students. We have focused our interest on computer programs developed by the Consortium for Upper-Level Physics Software (CUPS)[2], which cover a wide range of physics items, and the Software Teaching of Modular Physics (SToMP) programs[3], which are more complete education packages covering a small number of physics items. The experience we have gained from using the computer in the teaching process has led to the design and implementation of courses where the use of computer simulations has been an important part from the beginning.

Implementation of CUPS programs

The CUPS programs in Mechanics and Quantum Mechanics have been rather extensively used[4]. The Quantum Mechanics program was introduced and used as a pedagogic tool in the introductory course in Quantum Physics given during the fifth semester of the physics studies. The main part of the course was defined by the existing textbook, which covers the normal topics of a first course in quantum mechanics. The programs were used during the lecture sessions either as planned demonstrations or as illustrative material. The programs were also frequently used during the discussion sessions. The CUPS programs provide a simple way to construct and modify situations that are normally difficult to show with transparencies; e.g. display of different potentials and the solutions to the Schrödinger equations for these potentials, and penetration and scattering of particles of different energies by various potentials. The students were encouraged to explore the quantum mechanics package on their own and many students did.

We have also used the CUPS packages in Mechanics and Waves and Optics. Many of the CUPS programs illustrate, in a very instructive way, phenomena in mechanics and wave motion. In most programs the effect of varying important parameters can be well studied. The programs have also been used to find numerical solutions to more difficult problems, like finding the frequencies of the normal modes of a complicated system of coupled oscillators. Up to now the CUPS programs have mainly been used for demonstrations during the lectures. However, the CUPS programs are also available to the students for individual training and problem solving. The programs and textbooks include many illustrative problems for individual training.

Quantum mechanics for chemists (Computer Chemistry)

The experience from the pedagogical experiment was used in designing new courses given in the spring of 1997 where the advantages of illustrative computer demonstrations were found to be even greater. The result was a course in "Computer Chemistry" given at Stockholm University and the theory part of a course on "Catalysis" given at Chalmers Institute of Technology, Gothenburg. The quantum mechanics course for chemists is completely new and comprises 10 weeks. The part given by the physics-based quantum chemistry group corresponded to three weeks of lecturing and the task was to introduce the students (second year chemistry students with no mathematical or quantum mechanics background) to quantum mechanics and quantum chemistry. The challenge to discuss the consequences of the Schrödinger equation and its application to problems in chemistry with such little time available and to such a mathematically unprepared group of students was very successfully solved using the computer. This allowed a discussion of the models and of the properties of the solutions and the qualitative aspects of

quantum mechanics and was very much appreciated by the students. For the initial teaching of quantum mechanics, the CUPS program on Quantum Mechanics was extensively used. The second part of the course was based on the MacSPARTAN program[5], where the molecular Schrödinger equation is set up and solved at different levels of approximation.

In summary, the most important contributions to the teaching from the use of these computer programs in the Computer Chemistry course has been the flexibility to set up models and to solve them interactively in a discussion form with the students. The computer program brings forward the contents of the solution while eliminating the mathematical intricacies, which can be discussed much more easily at a later stage when the students are ready for it. More details about the course can be found in Reference 4.

Implementation of SToMP programs

The philosophy behind the SToMP packages is quite different from the CUPS programs. The program package is very large and complete, containing a lot of text, background material, illustrations, video clips and interactive exercises and can more easily be used for self studies. However some tutoring is required in order to profit fully from its capacity. The SToMP programs have been used as attractive complements to the standard textbook in the Fields and Waves courses. Three different courses have been given for a total of 160 students. Also the SToMP package on measurement uncertainties has been used in the courses.

Environment for the Computer Aided Learning implementation

A large amount of effort has been devoted to create a constructive and creative environment for the teachers where Computer Aided Learning can be studied and the implementation strategy can be worked out and tested. The introduction of new teaching methods, like a more systematic use of computers, involves changes in the way physics has been taught before and the teaching tools used. We have organised seminars, demonstrations and workshops, very often with invited speakers from the international physics community. We have also constructed the Teaching Development Laboratories to provide a laboratory where new teaching material can be studied. To interest and stimulate the teachers has been one of the main aims of the FLIP project and the creation of a good environment for the development of physics education has been one of the main successes of the FLIP project.

Summary

We have successfully implemented the use of teaching packages like CUPS and SToMP programs as well as producing our own courses where the use of the computer plays an important role in describing and explaining physical processes. An important part of the work has been the critical study of existing material and selection of the parts that fit in the existing courses. One of the main successes of the FLIP collaboration is the creation of an inspiring environment for the development of Computer Aided Learning in Physics. We have explored and successfully used the computer as a tool in several physics courses at both the Royal Institute of Technology and Stockholm University and have given support to the teachers in their implementation work.

References

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5. *MacSPARTAN*, registered trademark, http://www.wavefun.com/software/software.html

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