The Integration of Software into Courses

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Introduction

This paper discusses the problems of introducing new teaching methods into undergraduate physics courses and then describes how the SToMP (Software Teaching of Modular Physics) project courseware was designed to overcome some of these.

Design Considerations

The essential components of most university physics modules are lectures, tutorials, assignments, laboratories and self study.

Lectures are used to describe ideas and concepts. These are multimedia presentations involving speaking, writing, drawing, using pre-prepared diagrams, demonstrations, and perhaps video clips and computer simulations. They also allow two way interaction between lecturer and students, although this is not always taken advantage of.

Tutorials offer an opportunity to repeat the ideas and concepts, often in different ways and styles, and usually in response to students' questions or perceived lack of understanding.

Assignments are set to provide some sort of feedback on a student's progress, but mainly to encourage the students to use the concepts that have been introduced. The problems require students to apply the concepts and principles in new ways to new situations, so that they exercise their understanding.

Laboratories are designed to allow students to learn experimental techniques and it is generally agreed that students must do practical experiments in laboratories to gain the necessary experience. Laboratories also provide exercise in data acquisition, data analysis and presentation, and encourage students to interpret and critically assess their results.

Self study is used by students to consolidate the ideas, the techniques and the concepts learnt. Self study is the main self paced activity currently undertaken by students. It encourages them to develop their study skills and to achieve a deeper understanding of the subject.

Can Computers Help?

Using interactive models can help concept development. Computers are particularly useful to physics students as a means of displaying representations of physical phenomena which can sometimes be difficult to conceptualise when only described. A computer simulation can be built that will output status information in pictorial, graphical or numerical form as input values are varied by the user. In this way the user is not required to carry out repeated numerical calculations that might otherwise get in the way of understanding.

Animated diagrams can help demonstrate complex concepts. Multidimensional (particularly time varying) functions are difficult for students to visualise with just static diagrams. Moving diagrams and animations are more memorable, and often help students come to a better understanding of the physics.

Regular testing of progress can help maintain standards by showing the gaps in a student's knowledge. Using computers for such self assessed testing is advantageous because it is both objective and impersonal. Once such a scheme has been set up, it can also be simpler to administer than conventional tests and thus involve less staff time.

Software tools can help students manipulate data faster and more accurately than by hand. The use of data analysis and graphing software is common practice in research and development, and is in widespread use by undergraduates in many countries. Students need to develop skills using these tools to prepare them for their subsequent employment. The use of such tools should not compromise the necessary understanding of the arithmetic processes involved, however.

Problems with their Use in Physics Courses?

Using interactive software requires a motive for most students to use them effectively. Conventional software models offer a wide range of input settings, visualisation modes and other options. They can be confusing for students to investigate and, unless directed with care, a student can leave such a program without having observed all the important situations. Such software usually needs to have problems set that require it to be used to solve the problems. Problems that can only be solved this way can be difficult to set, however, and so the use of such software can sometimes appear rather artificial.

Students must be allowed time to use software provided for their benefit. This means that sufficient facilities must be provided, and available at times that the students are free. It is best if sessions can be put into the timetable so that students are guaranteed access to the computers, particularly if staff are also scheduled to be there to help them. A common problem, however, is that students' timetables are so tightly constrained that in order to find time for such a computer laboratory session, some other component of a course will need to be removed. This situation is exacerbated if, as is frequently the case, a complete year group is too large to use the available computing facilities in one sitting.

What Could Be Removed from a Course?

Self study is by definition a component of a course that is organised by the student irrespective of the work undertaken or of the institutional facility used, be it library, computer laboratory or study. Thus self study can only be replaced by another form of self study, since the time management must be left to the student. Therefore, timetabled sessions are not appropriate.

In a similar manner to self study, the assignments that students are required to do can only be replaced by other assignments. Whatever means are used to accomplish the assignments, part of the exercise is again the self management of the student's time, and so timetabled sessions are again not appropriate.

Tutorials are an activity that could, in theory, be replaced at least in part. One of the outcomes of the successful use of new teaching and learning techniques is that understanding will be improved. In this case, there might be a reduction in the total time required for tutorials. The total replacement of tutorials, however, would require a teaching and learning environment based upon an artificially intelligent system. Whilst this is probably the goal to which we are striving, it is clearly not yet available.

It is generally agreed amongst physics academics that there is a continuing requirement for students to do real laboratory experiments during their undergraduate training. It is arguable that some experiments are better done (at least for the first time) as computer based simulations, so that more efficient use can be made of laboratory equipment. It is also clearly the case that some experiments can usefully be provided as computer simulations because they cannot be carried out in the laboratory for reasons of size, cost, danger or other impracticality. In this case, there might be a reduction in the total time required for 'real' laboratories, but this is not certain.

It is the suggestion of the author that lectures themselves are not required, although there is no doubt that the planned outcome of a lecture course (i.e. student learning) is required. If the same result could be achieved in a different way there would not appear to be any academic requirement for the lectures as such. Some teaching and learning development projects (including the SToMP project) have therefore directed their efforts towards the design and implementation of effective lecture substitutes. It should not be assumed that the integration of such courseware into a conventional course is necessarily straightforward. Appropriate sections must be selected to match course requirements, access must be arranged to suitable computers, the students must be convinced that the use of the software is in their best interests and sympathetic staffing of the laboratories must be arranged.

Other Justifications

Lectures are probably the least effective teaching tool used in undergraduate courses. It is the common experience of most lecturers that it is difficult, if not impossible, to maintain the interest of all students attending a lecture all the time. This is largely because it is very difficult to introduce any flexibility into a lecture presentation, so that whilst the pace of a lecture might match the students' requirements on average, the majority of students will suffer a presentation that is either too fast or too slow. Another factor that mitigates against lectures is that the approach used for any topic will probably not be the best for all students. It is the experience of the author that some students conceptualise analytically, some graphically and some pictorially, but that an individual student might not be consistent between different topics. If this is true, then it is clearly an almost impossible task to present new concepts and ideas to a large group of students in a way that stimulates all those present.

Despite these limitations, lectures undoubtedly do perform a useful function. They define the content of a course and present the required theory and ideas to the students. They can personalise the course material, clarifying its relationship to other topics within the discipline, and a good lecturer can enthuse students to a lasting interest in topics that might otherwise appear uninteresting. It has been established during trials of SToMP project materials that most students do not like the idea of a new teaching system that will replace all the lectures of a course.

A Solution

Considerations such as those discussed above have led several projects to design systems intended to provide a complete course on a computer. Such systems aim at providing the same sort of guidance that lectures provide but, being on a computer, other materials can also be included that take advantage of the power of the multimedia system. A science package (such as SToMP) will therefore contain many interactive models, sound files, pictures and video clips, as well as the directed teaching texts.

The SToMP design was based upon an implementation of distance learning principles, so that if necessary it can be used completely by itself; in the same way that some people have managed to learn physics from just reading the text books. As a text book substitute, however, the SToMP materials provide a more effective learning environment since they also contain background materials, software tools and other resources.

Integration of such courseware into a course still requires careful planning, however. For example, the removal of a single lecture to make way for multiple laboratory sessions (if a class has to be split into more than one group to get it into the laboratory) can be a stumbling block with colleagues and a persistent timetabling problem.

Using SToMP

The first two modules were completed and published in the autumn of 1995, although earlier incomplete versions had been trialed with students as early as the summer of 1993 and again in the 1994/5 academic year. These latter trials involved the replacement of lectures with timetabled, academically supervised laboratories, and the results of these trials have been published in a report and in papers. SToMP has also been provided as a self study resource in some institutions, and some staff have also used SToMP simulations and animations in lectures as demonstrations.

When used in place of lectures, it is recommended that only a proportion of the total lecture time is replaced. As stated above, students are unhappy if all the lectures in a course are replaced, but several models have been tried successfully, that allow SToMP to replace just some of the lectures. In one arrangement one lecture in three or four is retained and used for covering key concepts and for defining topics to be covered. Another arrangement, where two hour sessions were timetabled, involved a 15 minute introduction to each session. Alternatively, where there is more than one timetabled lecture a week, one lecture might remain and the other timetabled as a computer laboratory. In practice, the constraint is usually the timetable itself, or the problems of fitting a large class into a laboratory of limited size.

In any such arrangement of lectures and SToMP sessions, the presence of academic staff in the timetabled laboratories is recommended. This has been found to provide a good opportunity for staff to discuss the physics with students on an individual basis, expanding the range of interactions between staff and students.

A serious problem with expecting SToMP to be used as a self study resource only, is that students are generally found to be unwilling to undertake additional activities that they do not see as being essential parts of a course. Thus, it is necessary to make it clear which parts of a course are to be covered in this way, and it also needs to be clear that this component will be assessed.

The SToMP testing facility has been used widely in self test mode and students find the facility useful in providing immediate confidential feedback to their attempts (no record is kept of each student's responses). The assessed testing aspect of this tool has been developed more recently, but has now been trialed successfully in the formal assessment of students at one establishment. This trial was carried out as a mid semester progress test, with a year group of 45 students and a set of questions written for independent use. The students were unsupervised whilst taking the tests which were available over a two week period, but each test had to be completed in one sitting. The system will not allow a student to make more than one attempt at the test. At the end of the two weeks, the students responses in the database were marked automatically. The marking program produces a table of marks for the group of students, and can optionally show the date and time of starting, the length of time spent on the test, the individual marks for each question, and the raw responses of each student for each question. Where the question involved the generation of random numbers, these are also written to the data base and can be displayed.

Conclusions

The SToMP style of teaching and learning material was designed to address many of the issues involved in the introduction of computer based teaching and learning materials as a replacement for traditional components of a course. There are many issues involved in the successful integration of such packages, and the wide range of organisational and educational requirements at different institutions requires full and imaginative advantage to be taken of the inherent flexibility of these new multimedia course modules.

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