STоMP: A Dynamic Approach to Courseware Development.

James L. Hunt,
Department of Physics,
University of Guelph,
Guelph ON, N1G2W1,
Canada.
phyjlh@physics.uoguelph.ca

Richard Bacon,
Department of Physics,
University of Surrey,
Guildford. GU2 5XH.
U.K.
r.bacon@surrey.ac.uk

Abstract: SToMP (Software Teaching of Modular Physics) is a comprehensive software package designed for use in introductory level undergraduate physics. It provides the student with carefully written scripts augmented with activities, simulated experiments, references, glossary, historical material, and media clips which are displayed in an easy-to-use format exploiting the multi-windows computer environment. The material includes self- and assessed-tests for each module and an array of tools (calculator, spreadsheet, grapher etc.) which can be accessed from any point within the package. Two modules have been completed to date: Measurement and Uncertainty, and Waves and Vibrations. Other modules are in various stages of preparation.

This paper looks at the pedagogic rational for the SToMP system, and discusses modes of integration into existing courses. The system is dynamic, and is able to subsume new developments, some of which are described.

1 Introduction

Computers have been used in Physics for many years for many purposes, and attempts have been made for over twenty years to use them in the teaching of physics (e.g. Hinton 1977, Boardman et al 1988 and Wilson & Reddish 1992). During this time, however, no one method of using computers to enhance the teaching and learning of physics has emerged as a universal solution, and no two physics departments seem to use computers to aid teaching in the same way. This paper briefly discusses the problems of the introduction of IT-based teaching methods and why their use has remained marginal. It then introduces the Software Teaching of Modular Physics (SToMP) approach to meeting the needs of current problems in undergraduate physics teaching and learning. This approach has been developed by a consortium of academics within the Software Teaching of Modular Physics project. SToMP includes an efficient development environment, a consistent student interface and an integration mechanism that is widely applicable.

SToMP courseware takes advantage of all available computer-based media types and is inherently open to teacher and student. However, it has established guidelines and standards by which the media can be integrated in a structured manner and used to direct learning within prescribed curricula.

2 The SToMP approach

Conventional science teaching usually involves the following student experiences,

- lectures and seminars, augmented in some cases by video and demonstration.
- tutorials and problem classes.
- laboratory work, often linked with practice in the presentation of information.
- individual problem solving and essay writing, often linked with assessment.
- project work, often linked with the use of information sources.

From a student's point of view these can often form a set of only vaguely linked aspects of the same subject. Topics within a physics course tend to be compartmentalised, and laboratory experiments are often badly out of step with the presentation of the appropriate theory in lectures. The use of an appropriate delivery mechanism for a topic, or the inclusion of a new student activity at an appropriate point, is hampered by the rigid structure of course modules imposed by timetabling, logistic or other constraints. These sorts of problems are particularly relevant to the introduction of computer-based materials into existing courses that are already tightly constrained by staff commitments and limitations in student contact hours. Also, many departments are experiencing difficulties in finding funds to equip laboratories for large first year courses and are turning to computer based simulations (dry labs). With the timetabling constraint thus removed, these 'experiments' can be integrated into the courses at their proper time.

From the student's point of view, the introduction of a new computer based component to a course, in addition to existing activities, will not necessarily be taken seriously unless it is clearly an integral part of a course [Laurillard 1993]. This usually means that there has to be an obvious link with the course assessment.

The SToMP project has attempted to address these problems by providing a richly linked set of multimedia documents, interactive experiences and assessments that can be used as a replacement for some components of existing courses. The flexibility of the environment can also help improve the necessary conceptual linking between the disparate aspects of a course.

3 SToMP, a highly integrated system.

Each SToMP module comprises a complete and open learning environment that contains all the material needed for an in-depth study of areas of physics covered by that module. Two modules have been completed so far, Waves and Vibrations, Measurement and Uncertainty, and others such as Optics are under development. The completed modules contain over 100 hours of study material that can be used in place of conventional lectures as the principle teaching vehicle of a course. SToMP resources are best augmented by the usual tutorial support mechanisms and may be further enhanced by locally produced materials.

A SToMP module is logically structured into blocks which are further subdivided into units, each of which has a sparsely written but didactically complete teaching script. This leads the user through required subjects and arguments in the order required for suitable concept development. Modules are also provided with a rich resource of background material including sections from appropriate text books, video and audio sequences, pictures, animations, assessment material, a glossary, and other reference items such as data books and biographies. All the material is structured and indexed, and may be accessed via several information retrieval mechanisms. In addition there are a large number of interactive physical simulations and experiments that are introduced from the scripts together with documents describing how they can best be used [Fig. 1]. Students on a set course are expected to access the material by following these scripts. The layout of these provides consistent navigational cues to the importance of the linked material. The teaching strategy emphasises active involvement, with students being directed via questions through activities in a choreographed investigative manner. As part of this teaching strategy, scripts also contain problems which can require users to access other documents and resources in a more open-ended manner. The material included within each module is intended to be a superset of that which would be appropriate for any given course. This redundancy of material helps ensure flexibility of use, and is assisted by the built-in tutor's-notes files, which are designed to be edited by each course tutor.

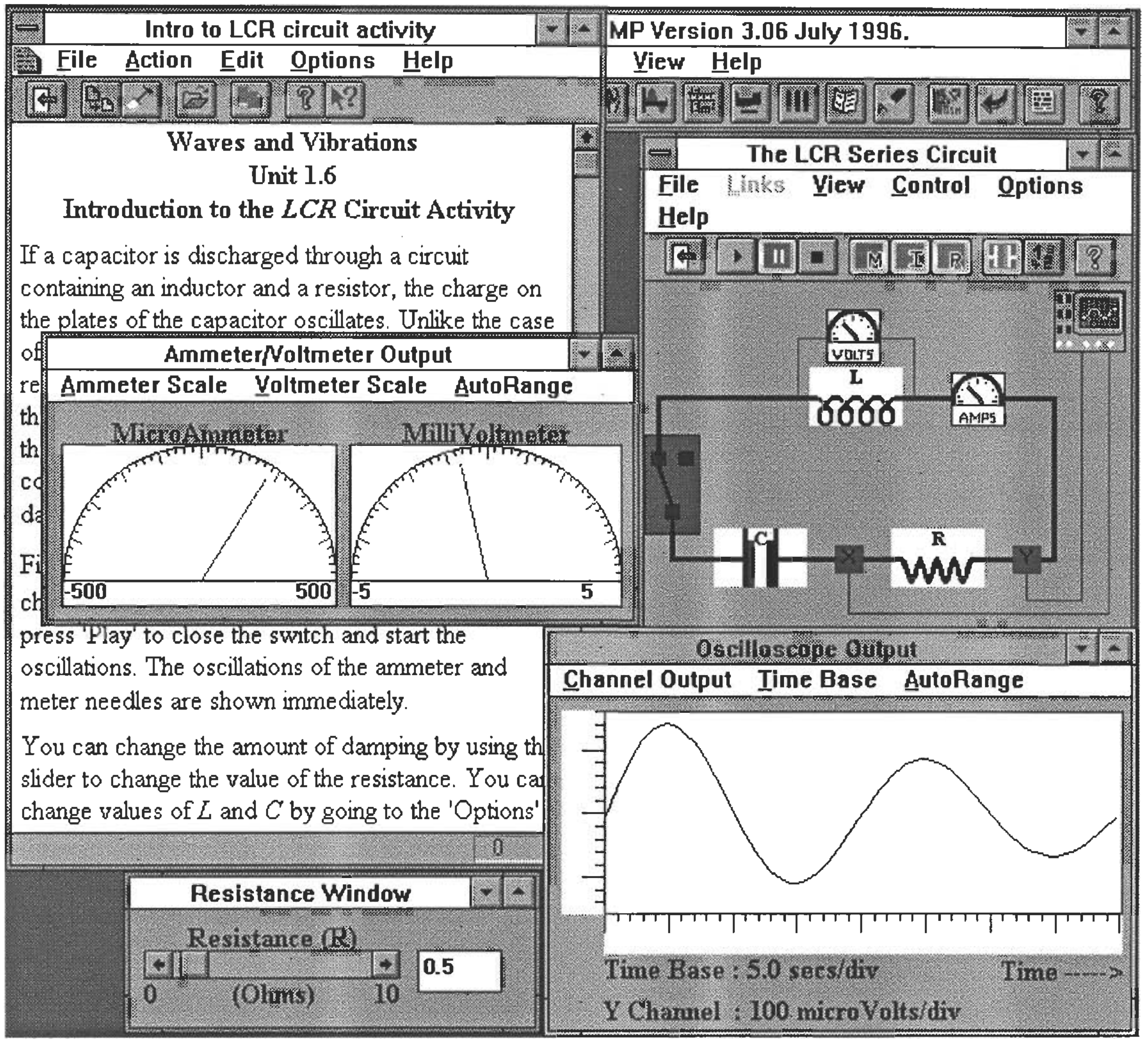

Figure 1: An interactive physical model of a series LCR circuit, with meters and oscilloscope, together with a descriptive introductory document.

In addition to the resources and activities described above, the SToMP environment also contains an integrated set of subject-specific tools that can be used in conjunction with other features for problem solving or for project work. These include calculators, a simple spreadsheet, a graphing package, a word processor, and a data conversion utility. Using these, the student is encouraged to see SToMP as a mechanism for 'doing' physics as well as learning about it.

4 Integrating SToMP into existing courses

The advantages of the 'complete environment' approach become clearer when the details of course integration are considered. The system can be used as a direct replacement for lectures and tutorials instead of creating a need for additional contact or laboratory time. The role of the teacher then changes from lecturer to mentor, so that there is more time for one-to-one or one-to-few discussions and explanations and less time need be spent on preparing the details of course presentation. The system uses a range of techniques to present theory and to relate it to the real world, and access to these resources is totally under the users control. This implicit tailoring to the needs of each student leads to self-paced progress that can match the learning style of each individual. The impersonality of the student's interaction with the computer may provide an additional advantage - students are sometimes hesitant about admitting ignorance to their tutor, but are less inhibited about accessing remedial help on a computer. It is important to emphasise that the material is open to students to add their own links, and to the tutor for adding both documents and links. At the simplest level, empty shell documents (tutor's notes) are included for the lecturer to provide study-guide advice to the institution's own students. At the other extreme, additional documents can be added incrementally and linked in to provide locally relevant emphases.

This integrated approach is a step beyond the piecemeal approaches often adopted in the guises of Computer Assisted Learning, Computer Based Learning, Information Technology in Education, etc. This system includes activities with relevant scripts containing descriptions and theory, problems and tests, and with appropriate background material being easily available. This creates the required environment for effective use of these resources that would otherwise need explicit definition by the teacher. The use of a standard user interface maximises the ease-of-use of the many components of the package, whilst the sophistication of a Windows based system supports the high degree of integration that the SToMP style requires. A multi-tasking environment encourages the use of a wide diversity of tools and on-line information sources within the learning activity.

5 SToMP use of windows

The windows user-interface is an important aspect of the SToMP learning environment. In a conventional (non-computing) learning situation, a student refers to several documents in one session, e.g. a text book, lecture notes, and the working of a problem, or, in the laboratory, the experimental equipment, the experiment instruction sheet, and a laboratory notebook. The windows interface implemented with a sufficiently high resolution monitor now supports this multiple document concept adequately, and such a multi-tasking interface is crucial to the effective use of the SToMP materials, which are designed to require several documents to be visible at the same time. For example, a test question may require a model to be used which in turn needs its own introductory text to be readable.

It is unfortunate that the early versions of the PC windows interface were available to the majority of users only on small, very low resolution monitors. This has had the detrimental effect of encouraging the 'misuse' of the interface by restricting applications to being run 'full screen', that is, to habitually take up the whole screen area with one application. It is only since the advent of higher resolution and larger size monitors that PC users are beginning to use their resources as effectively as UNIX windows users have since its inception.

An important factor for developers is the high quality and increased ease of use of the tools available for creating windows applications as compared to earlier DOS-based compilers. These not only enable quick and easy access to all the commonly required windows features but also support mixed language development by means of libraries of utilities or applications that are only linked at run-time (Dynamic Linked Libraries - DLL's). There is also a well defined and simple-to-use 'help' compiler, that allows for the speedy preparation of user support for each application.

Another factor that is contributing to the effective development of this style of integrated learning package is the emergence of standards for the presentation of the different media types within the windows environment. Despite the wide variety of hardware implementations of PC's, including the different sound cards and screen driver hardware, materials prepared to these standards perform in similar ways on different machines. In addition, and this is another important feature of the SToMP package, user institutions can prepare their own additional material of any media type, confident that it will integrate with the rest of the package in a seamless way. The Microcosm Document Management System [1] used by the SToMP project allows such incremental additions to the linkbase to be achieved with minimal effort.

The windows style of interface is thus clearly an important enabling feature of the SToMP style of learning environment that requires users to access several related documents simultaneously. This use of windows can be much more than just the ability to have several documents open on-screen at one time. It can involve the copying of text, data, graphics, or other information from relevant sources into destination documents being prepared, for example, as private notes or as an assignment, or data into a spreadsheet for analysis.

6 Looking to the future.

The features that have been included in the SToMP materials to date are limited to those we have been able to either find or produce, that are of appropriate quality and style. The usefulness of this or any similar environment will be improved, in principal, if we can include additional features (e.g. more background reference material), more scientific tools (e.g. an integrated algebraic manipulator such as MAPLE), further experiment simulations, or the additional modules required to provide a complete coverage of the first year syllabus. The usefulness of this style of environment will also be improved if the necessary computing skills to use it were acquired by students before reaching higher education. The lack of these skills seems inappropriate given the almost universal use of computers throughout all information based employment. We suggest that computer skills (touch typing and common interface usage) should be added to the basic skills that are a core part of secondary education. This would make a significant impact on the efficiency of use of computers in higher education, and on the accessibility of integrated packages such as SToMP.

One of the most important developments of SToMP is currently the extension of the integrated assessment mechanism. SToMP modules include not only self-evaluation questions within scripts (a useful didactic device that has been increasingly adopted in text books in recent years) and investigations which require the student to use the SToMP tools to answer questions related to the relevant module, but also automated tests with the question styles ranging from simple multiple-choice identification, through pair-matching from lists, to problems requiring a numeric input. In the self-test mode these tests are important as a means for student's self-evaluation and are particularly appropriate in a self-paced learning environment. In assessed mode they are an obvious means by which teaching efficiency can be improved without sacrificing quality and, if summative even at nominal levels, would motivate the students to use the material thoroughly. We are currently increasing the number and quality of both self and assessed tests within the SToMP materials, and we are also improving the security of the system for assessed tests.

It is interesting here to note the heavy use made by mass education institutions (e.g. The Open University, UK.) of machine-based continuous and examination assessment. The economics of such methods are compelling when student numbers are high, as they must be when the course presentation mechanisms are expensive and capital intensive (as they are in projects such as SToMP).

With the emergence of 'complete courses' available via a computer as described here, the issue of access to machines by students is another factor of significance. Different institutions are adopting different strategies to achieve this end, from 'giving' a computer to each student (as at Brighton University UK), requiring that newly entering students have one (as at Acadia University in New Brunswick), through to providing 24 hour access clusters. Whilst the actual mechanism is not too important, it is obvious that there is a closed loop in which the investment has to be justified by use, which in turn leads to more investment, until the ratio of machines to students reaches 1:1. This would still not solve all the problems, however, because of the two apparently

[1] Microcosm is a registered trade mark of Multicosm Ltd., Southampton, England. http://www.multicosm.com/

conflicting requirements - that students can work at home with their computers, and also are able to work in supervised laboratories.

There is a distinct convergence between the approach we are adopting within the scope of the SToMP packages and the rich linking that is now implicit in, for example, World Wide Web or Hyper-G [Andrews et al 1995]. We might speculate on the opportunity of augmenting a local learning environment (with sets of documents and links) with a more comprehensive set of documents. This could enrich the overall range of learning experiences without necessarily introducing significant time penalties or diluting local autonomy.

Looking a little further into the future, the use of artificial intelligence to improve the learning experiences of users of packages such as SToMP will conceivably challenge the quality of teaching obtained at Universities that use individual student tutoring. In a lecture, the pace of presentation is controlled predominantly by the lecturer who is unable to cater for all requirements. As the ratio of staff to student improves, the matching of presentation rate to acceptance rate improves, but only as the ability range of the group narrows. One student with a skilled tutor will learn at the optimum rate because the tutor will match presentation and discussion to the perceived rate of concept development, often attempting to 'stretch' the student. The current style of SToMP provides material at the rate demanded by the student, but does not provide much incentive for an able student to go beyond the stated minimum requirements. An artificially intelligent (and highly interactive) system would be able to match a student's requirements in a way that maximised their individual learning potential.

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