Introducing the SToMP Mechanics Module

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Introduction

The SToMP project (Software Teaching of Modular Physics) has been producing multimedia self-learning materials for undergraduate physics courses since 1992. Over the last three years a new module in Mechanics has been implemented, and other features of the system have been improved and updated. The underlying philosophy of the system has remained unchanged, however, although modes of use have developed with experience.

Self-learning materials are becoming increasingly important in first year undergraduate physics teaching, as the diversity of backgrounds and experiences of new undergraduates increases. Student driven, self-paced resources allow students to reach targeted levels of understanding and skills without incurring too great a demand upon staff time.

The SToMP style

The SToMP style of self-learning materials include text documents containing theory and explanations hyperlinked to interactive physical models, animations, video clips, diagrams and other documents. Previous research had shown that educational software could enhance understanding of scientific skills and concepts when it enabled users to investigate scientific processes (e.g. Cox and Burge 1978). The organisation of these materials and their interlinking was designed to maximise the integration of the theory with application, so supporting informed investigative use.

A SToMP module typically contains about 1000 documents (of all media types), including a common reference section containing a glossary, databook and sections from relevant textbooks (except for the Mechanics Module). In order to facilitate open access to this large number of documents, several alternative linking, searching and browsing mechanisms have been provided. These include a document 'explorer' provided with alternative conceptual structures (block and unit v document type), a keyword browser and a word or phrase search facility.

Assessment is addressed in several ways within SToMP. Simple questions are often included within text documents, in order to encourage student users to think about the topic. Answers to these questions are readily available to the user, but are not immediately visible. Conventional problems are provided in many units, with some answers being provided in adjacent documents. An automatic testing system is used to provide self-tests and assessed tests for many units. This system, developed for the SToMP project, supports conventional single and multiple choice questions as well as random numeric questions that can check the precision as well as the accuracy of the answers. Self-tests provide useful feedback to the student that can be targeted at specific wrong answers, whereas the assessed tests provide no feedback, but save each student's responses to a database for later (automatic) marking. This system has been significantly improved recently, and is now much simpler to implement than the original version.

Mechanics

A new SToMP Mechanics Module (other modules are 'Measurement and Uncertainty', 'Waves and Vibrations' and 'Optics') has been released during the summer of 2001. This module comprises 26 units aimed at first year (English) undergraduate physics courses (17/18 year olds), and covers forces, work, momentum and energy in linear and rotational motion, collisions and oscillatory motion.

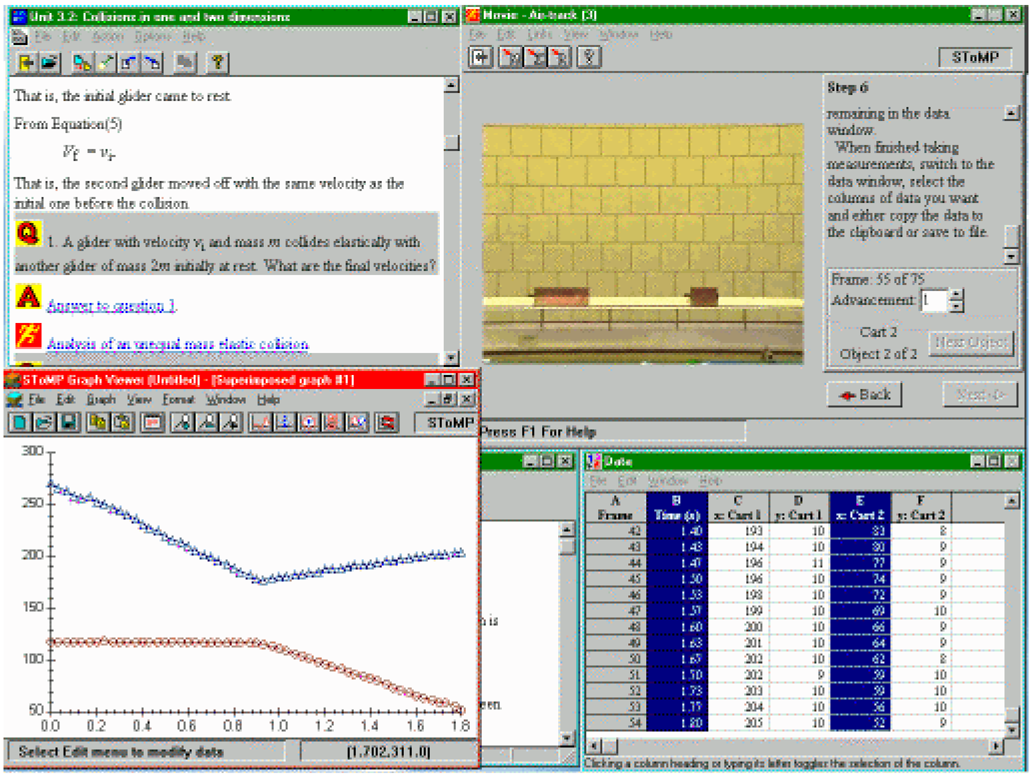

Figure 1. Analysing collisions between air track 'gliders'

As an example of one of the ways in which SToMP involves the student in relevant activities, consider the scenario illustrated in Figure 1.

At the top left, part of the theory 'script' for Unit 3.2 in the Mechanics Module is visible. A video clip of an elastic collision between equal masses (gliders on an air track) has just been shown, and expressions have just been derived for the final velocities of two gliders of unequal masses. The question invites the user to apply the equations just given, either on paper or mentally, before looking at the solution provided. (Underlined text is a link to another document that will open in a new window.)

The next link (preceded by a running man icon that indicates it is an interactive application of some sort) 'Analysis of an unequal mass elastic collision' opens the video analysis tool shown at the top right. It also opens an explanatory document (part of which is visible behind the graph at the bottom left). This describes what the user should do to take position readings of the gliders from the video, how the data should be displayed, what momenta should be calculated and what outcome should be observed. Such documents are commonly used within SToMP to provide the necessary support for each activity without impinging on the theory scripts.

The data collection window shown at the bottom right is part of the video analysis tool. Clearly, only the two columns of x data and the time data are relevant in this case. The user is advised to copy the relevant data columns and paste them into the graphing viewer. This viewer (shown at the bottom left) is one of the software tools provided with SToMP, although alternative tools may easily be substituted.

A second example is shown in Figure 2, where a constant acceleration in two inertial reference frames is being discussed. At the top right can be seen the SToMP 'floating' toolbar, which provides access to software tools and other system features such as the document selection window shown below the toolbar. The interactive model of 1D reference frames was started from the document selection window, where it is one of the 12 main documents of Unit 1.2. As before, an introductory document is automatically displayed (shown at the bottom left) explaining what is being seen, and inviting the student to investigate parameters relevant to the topic for which the model was provided. The theory script for Unit 1.2 was in this case opened from the model - a link is provided in all appropriate interactive models, helping to bind theory to experience whatever route a student takes through the material.

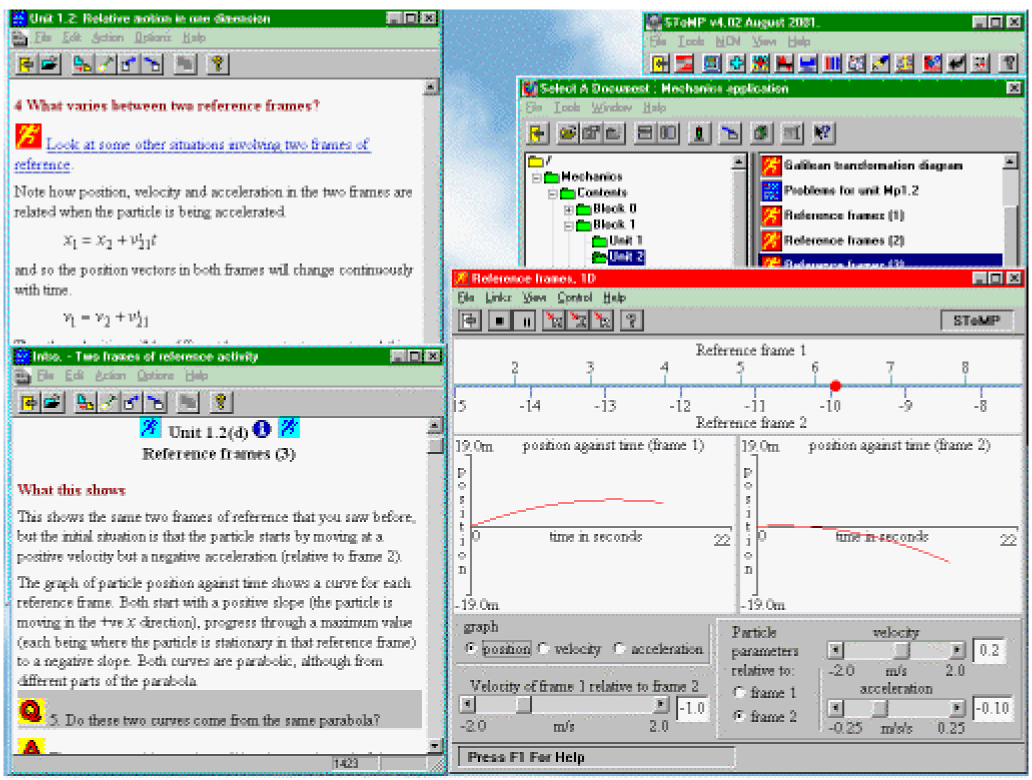

Figure 2. Navigating from a physical model to relevant theory

Assessment

The assessment tool used in SToMP was commissioned by the project, in order that the tests integrate with the rest of the system, and that the style of questions required for physics problems would be supported.

When test questions are being answered, a student can therefore link to other SToMP documents using keywords or word searching facilities, can browse and use interactive activities, etc. This is seen as an important part of the learning process, and indeed one of the recommended modes of use is based upon the use of the assessment.

The testing system is used for both self-tests (formative) and assessed tests (summative). Whilst it is appreciated that summative testing can (and usually should) be formative if appropriate feedback is given at the same time as the work is assessed, in this system the two are kept separate. The self-tests can provide detailed feedback, based upon the answer given. It is possible to isolate every possible wrong answer in the single/multiple choice, and the rank ordering and pair matching question styles. Where the number of possibilities is large this is impractical, but in these cases generic wrong answers can also be detected and dealt with. In numeric questions it is possible to check the number of significant figures as well as ranges of values. It is also possible to check alternative expressions, so that conceptual or other common errors can be addressed. Similarly, when used in assessed mode, the marks for each question can be finely tuned so that answers need not be either right or wrong. This is particularly true of numeric answers where values are often quoted to incorrect precision.

The assessed testing system has recently been re-organised to render it easier to implement. A single online database is provided at the University of Surrey, UK, although a local MySQL server can be used instead if desired. Course administrators can access the database to set up class lists and to schedule each test with start date, end date and numbers of tries each student may have. After the test (or during it) the course administrator can mark students' work to date, and can then copy the results into their own spreadsheet for any further processing. The information provided by the marking software includes both the start and the submit date-stamp, the mark for each question together with each student's verbatim response to each question. Where multiple tries have been permitted, the marker supports marking all tries or just the last, and can indicate the number of the try.

Modes of use

The SToMP system has been under development since 1992, and has evolved considerably during this time. The original aims have not changed significantly, however, from that of creating materials that are appropriate for self-learning in situations where academic support might be minimal, such as in learning at a distance (Bacon and Swithenby 1996). The reason for choosing to aim at such a 'stand alone' system was simply that such materials should, logically, be applicable to the widest range of applications. Any other style of learning situation would be less demanding on the system.

In practice it has proved difficult to form any firm idea of how the system has been used within the institutions that have obtained it. The original conception had SToMP being used as a replacement for some of the lectures in an otherwise conventional course. Trials that were carried out during the first phase of the project pre-supposed this style of use and were not unsuccessful (Watkins et al. 1995).

It has been used in this way at Surrey, replacing some of the lectures on a first year acoustics course. Students worked through prescribed SToMP units in timetabled sessions in a computer laboratory, with academic staff on hand to discuss the physics and to help with conceptual difficulties. When the SToMP assessed tests became available (in about 1995) these were introduced, and helped focus the students and provided progress indicators for the academic staff.

One of the major uses of SToMP is known to be as an ancillary aid to students, that they can use in their own time to help with understanding, or for revision purposes. It is particularly difficult to assess the level of use in such situations, but sites are renewing licences, and so it is assumed that the system is being of use to the students.

The use of SToMP in true distance learning situations has not yet been attempted, as far as is known. The changes to the assessment system so that it can now be used from the CD-ROM version of SToMP, together with improvements in Internet-based communications, means that distance learning with SToMP could now provide a very similar learning environment to its use within a department. A communication utility such as *Microsoft NetMeeting* can support audio communications and a common whiteboard over a domestic Internet connection, and can also allow the student's screen to be seen. Distance tutoring and inter-student discussions with such facilities are realistic options, and more bandwidth allows more sophisticated use, such as the running of SToMP applications on the student's own screen by the tutor.

Another mode of use (that could be combined with other modes) is that of using the assessed tests as the motivator. Here, a series of end-of-unit tests would be assigned, with starting and ending dates in a sequence designed to lead students through the available units in the desired order. This obviously does not have to be the original order, and may well be dictated by the order in which topics are dealt with in an accompanying series of lectures or practical sessions. Students taking the tests should be encouraged to use the appropriate self-tests before embarking on the assessed test, and they should be introduced in a formal way to the SToMP materials and the navigational model, and to its availability from either type of test.

The self-tests make clear to the students in a confidential way, where they need to do further work. The formative feedback is designed to be positive, and links are often provided to appropriate materials via keywords built into the test questions. Students can then proceed to the assessed tests when they feel ready, and even when taking this test they can still access the resource materials if need be. The marks from the assessed tests should be included at some suitable weighting in the final course assessment, in order to persuade students to do the work in the first place, but the marking is automatic, and so no extra work is involved on the part of the academic staff.

It should be noted that the modes of use described here do not ignore the role played by academic staff in the learning process. Such academic input is necessary for the majority of students, but the role played by academics can be significantly changed by the introduction of self-learning materials such as those provided by SToMP. In the conversational framework for the learning process proposed by Laurillard (2000), none of the media-only based systems are able to support all the communications and adaptations necessary for effective learning. The new role of the academic when using such materials is not necessarily less time consuming, at least in the first instance. When planning such introduction it may well be worthwhile to refer to appropriate case studies of the use of media based learning in your discipline (Trapp, Hammond and Bennett 2000).

Conclusions

The SToMP system provides learning materials, phenomenological experiences and assessment mechanisms into one integrated environment, and a new implementation of the system for Mechanics has recently been produced. The application of this environment is designed to involve little work on the part of academics, and several strategies for its introduction into first year undergraduate physics courses have been described. The system is flexible and provides a range of possible interactions together with a rich environment of resources.

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References

1. Bacon, R. A. and Swithenby, S. J. (1996) A strategy for the integration of IT-led methods into physics - the SToMP approach, *Computers and Education*, **26**, 135-141.
2. Cox, M. J. and Burge, E. J. (1978) CAL for Physics in J. McKenzie, L. R. B. Elton and R. Lewis (eds), *Interactive Computer Graphics in Science Teaching*, Chichester: Ellis Horwood.
3. Laurillard, D. (2000) Mainstreaming learning technologies: The role of practice, policy and partnership, ALT-C 2000, UMIST, September 2000. (available from http://www.umist.ac.uk/alt-c2000/programme/).

4. Trapp, A., Hammond, N. and Bennett, C. (2000) The Use of Communications and Information Technology to Support Small-group Teaching Activities in Psychology, *CAL-laborate*, **4**, 27-30.
5. Watkins, J., Davies, J., Calverly, G. and Cartwright, A. (1995) Evaluation of a Physics Multimedia Resource, *Computers and Education*, **24**, 83-88.

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