HSC Physics Virtual Laboratory

"Virtualab"

Simon Stokes / Chris Boshuizen / Graeme Dobbs

Open Training and Education Network / University of Sydney

simon.stokes@tafensw.edu.au / c.boshuizen@physics.usyd.edu.au

Introduction

The HSC Physics Virtual Laboratory is a physics resource utilising new technologies to deliver fully functional, highly interactive, virtual experiments and high quality audiovisual media, as well as providing a context for this media. It has been developed in response to the new Stage 6 Science syllabus and is consistent with the content, methodologies and practices that underpin the new syllabus.

The project developed multimedia production techniques for established platforms, to deliver photorealistic, fully functional apparatus and analysis tools for performing experiments and other highly interactive learning activities.

The experiments and learning activities developed form the core of a series of task-based, learner-centred Shareable Learning Objects through which the content of stage 6 science syllabus can be delivered. These Learning Objects have:

- one or more clear and explicit learning outcomes
- a conceptual introduction to prime the learner for performing an activity
- a real or virtual environment for pereforming an activity
- a 2-dimensional instruction matrix for delivering learner specific scaffolding
- facilities for recording information
- a discussion of theory relating to the activity

The resource generates sequences, experiments and activities in real time, according to input variables controlled by the user. It provides a conceptual framework for each of these activities through introductory material and theoretical discussions of all experiences. It provides tools for analysis of experimental data and an environment for recording, discussing and sharing experimental results. It orders and sets the activities within a solid real world context that provides a meaningful and consistent teaching and learning path.

The project

There are three primary areas of consideration that motivated the development of the HSC Physics Virtual Laboratory; a new syllabus, new teaching and learning methodologies and new technical standards. The project also provided an opportunity to investigate appropriate technologies for flexible delivery of educational content.

A new syllabus

There are new HSC syllabuses in all areas of Science. Changes in the new Science syllabuses are considerably broader than in most other areas.

The new science syllabuses have an emphasis on contemporary science and a coherence of understanding which embraces not just all aspects of content but also a range of skills as well as contexts and views on the social impact of contemporary science.

The new syllabuses emphasise the development of student skills in planning and conducting investigations, communicating information and understanding, developing scientific thinking and problem solving techniques and working individually and in teams.

The syllabuses are based on a new pedagogical approach embracing learner autonomy, project based learning and a desire to foster life-long learning skills. As a result, the syllabuses are written as a collection of student outcomes rather than an explicit list of facts the student is expected to know. This project has endeavoured to encapsulate this change in teaching methodology.

The physics syllabus, like any document of its type, requires a certain amount of interpretation, but the student outcomes have been taken at face value. Our aim at each point has been to develop content, and a platform for the delivery of that content, which *best enables the user to demonstrate achievement of the stated syllabus outcomes.*

It is useful here to look at an example of a student outcome statement from the syllabus.

"**A student will perform an investigation and gather first-hand information to observe the occurrence of different striation patterns for different pressures in discharge tubes**." [Physics Stage 6 Syllabus 1999, p61]

The requirement of this statement is not that the students learn any particular piece of information (although knowledge of some facts is implicitly required), but that the student performs an investigation. How do you flexibly deliver the content of this type of syllabus in a manor truly consistent with the pedagogical aims of the syllabus?

Resources need to be appropriate not only in terms of the implicit content addressed by resources but also the manner in which the content is addressed.

Far from facilitating achievement of the outcomes of the syllabus, direct iteration of information often actually undermines a student's ability to demonstrate achievement of the stated syllabus outcomes, and inhibits the seemingly inherent human tendency to speculate, hypothesise and theorise. For instance if the requirement of the syllabus is that a student perform an experiment then, while a resource that shows the experiment being performed is better than nothing, it doesn't actually help in any way to facilitate achievement of the syllabus requirements. In many ways it undermines a users ability to do so.

With this in mind, new technologies or methodologies might well be required for *any* teaching and learning resource to properly address the high level objectives of the new syllabus. Resources like the one we are developing could ultimately be the most appropriate "recommended texts" for skill and/or outcome based teaching and learning.

It was also identified that for reasons of apparatus availability and/or safety, some experiments called for by the new syllabus could not be performed in some schools.

The syllabus also outlines a context for learning at various levels. These contexts are explicitly stated or implied by the Module and Submodule titles. The project has utilised the contextual information the syllabus provides and recognises it as an integral part of both the syllabus and our resource.

Pedagogical Approach

The project endeavoured from the start to move away from text based material and explore the world of truly interactive media. This decision drew heavily on the principles of constructivist teaching/learning, in particular the development of student-centred, task-based content.

Constructivist learning is based on students' active participation in problem-solving and critical thinking regarding a learning activity that they find relevant and engaging. Learners "construct" their own knowledge by testing ideas and approaches based on their prior knowledge and experience, applying these to a new situation, and integrating the new knowledge gained with pre-existing intellectual constructs.

A foundational premise of constructivism is that learners actively construct their knowledge. Rather than simply absorbing ideas spoken at them by teachers, or somehow internalising them through endless, repeated rote practice, constructivism posits that children actually invent their ideas.

Constructivism emphasizes the careful study of the processes by which learners create and develop their ideas. Its educational applications lie in creating curricula that appeal to a student's previous experience and understanding, fostering further growth and development of the mind.

Experience thus plays a critical or even primary role in the notion of constructivist learning, so students should be encouraged to inquire, explore, experiment and discover. Students should be given opportunities to actively construct their own understanding by building on existing knowledge and skills. Material should be presented in a variety of ways, acknowledging that students' learning styles differ. To ensure that students see a reason for learning the particular skill or concept the learning experiences will be real world scenarios that are familiar to the students.

When assessing learning the emphasis is on performance and understanding. Experience plays a critical role in learning so students should be encouraged to inquire, explore, experiment and discover.

Learners should be encouraged to engage in dialogue with other students and the teacher because when we explain and discuss an issue we are much more likely to understand it. Students will be encouraged to work together thus supporting co-operative learning.

The aim is to produce:

- Active learners who engage in interaction with and manipulation of the exploration environments that we construct.
- Learners who explore and strategically search through these environments.
- Intentional learners willingly trying to achieve cognitive objectives.
- Conversational learners engaged in dialogue with other learners and with instructional systems.
- Reflective learners articulating what they have learned and reflecting on the processes and decisions that were included in the process.
- Ampliative learners who generate assumptions, attributes and implications of what they learn.

New Technical Standards

The emergence of new information and communication technologies promises forms of delivery that support teachers and learners in new ways, enrich student's experiences, are potentially more effective for learning and offer new flexibilities for learners and teachers.

The project provided the opportunity to investigate the viability of Shareable Learning Objects consistent with both educational objectives and technical capabilities and standards. These standards aim to maximise the reusability (and thus hopefully the reuse) of educational material.

The project adopted the Sharable Content Object Reference Model (SCORM™) as the technical standard for material generated by the project. It was not a project requirement that all material meet the SCORM specifications, but that all material be compatible with the specifications and could be published as SCORM compliant material if required.

"Up-front investment is required to develop and convert training materials for technology-based presentation. These investment costs may be reduced by an estimated 50-80 percent through the use of sharable content objects that are:

- Accessibility: the ability to locate and access instructional components from one remote location and deliver them to many other locations.
- Interoperability: the ability to take instructional components developed in one location with one set of tools or platform and use them in another location with a different set of tools or platform. *Note:* there are multiple levels of interoperability.
- Durability: the ability to withstand technology changes without redesign, reconfiguration or recoding.
- Reusability: the flexibility to incorporate instructional components in multiple applications and contexts.

Procedures for developing such content objects are within the state-of-the-art, but they must be articulated, accepted and widely used as guidelines by developers and their customers".

[SCORM Overview Version 1.2 p1_21]

Project Objectives

As a product of consultation with key stakeholders, and in light of the areas of consideration discussed above, the following objectives were identified for the project:

1. Analyse the content and objectives of the new Stage 6 science syllabuses.
2. Develop pilot teaching and learning materials consistent with the content and objectives of the new Stage 6 science syllabuses.
3. Apply new teaching methodologies and practices to the development of flexible teaching and learning materials.
4. Implement new asset management methodologies and standards in the production of flexible teaching and learning materials (SCORM™).
5. Identify appropriate platforms for delivery of the materials developed, in particular, to investigate DVD, Web-DVD and Augmented DVD.
6. Develop efficient media production methods and practices for new media technologies.
7. Foster an interdisciplinary approach to resource design and development, and strengthen working relationships between participating institutions.

The Product

The pilot was to develop resources which use the power and creativity of new information and communication technologies to extend the traditional 'knowledge transfer' role of educational resources so that they deliberately and effectively target and achieve the higher order aims and objectives of the new syllabuses.

The pilot materials are intended to supplement existing stage 6 science material for use by teachers and students within the classroom and students away from the classroom.

After consultation with interested parties, the following section of the Stage 6 Science syllabus was chosen for the pilot resource.

- Physics Stage 6 Syllabus 1999
  - Module 9.4: From Ideas to Implementation
    - Submodule 1: Increased understandings of cathode rays led to the development of television

This section of the syllabus looks at the development of television, from the first observations of cathode rays to present. The core physics material covered includes qualitative and quantitative analysis of electric and magnetic fields, properties of waves and particles and the discovery of the electron.

This submodule was chosen because it provides an opportunity to model what will be predictably a popular topic within the new syllabus. It also corresponds with areas of the syllabus identified by the UniServe Science Teacher Reference Group as difficult to resource. Many of the experiments explicitly called for by this submodule would involve apparatus not available in all schools, or have serious safety health and safety considerations.

Product Objectives

In order to make sure that the principles of constructivism that underpin the new syllabus were fully realised by the pilot product, an ordered list of product objectives for a constructivist resource was identified. The order of the objectives is important and represents a process of construction of complex knowledge and understanding: from initial awareness of a phenomenon to complete internalisation of complex principles.

The pilot product aimed to:

1. Provide an engaging and accessible real world context for all activities.
2. Allow learners to perform primary investigations to observe, record and analyse physical phenomena.
3. Provide appropriate levels of scaffolding within which learners construct their own conceptual understanding of the physical laws and principles behind each observed phenomenon.
4. Encourage the development and articulation of hypotheses through calling for speculation about unseen results and for justification of responses.
5. Outline the formal definitions, language, and equations a learner would be expected to use to describe each concept, principle or law.
6. Provide guided opportunities to apply acquired knowledge and understanding in a range of contexts.
7. Promote the development of sound skills and practices through first hand experience and direct application.
8. Provide opportunities for collaboration, discussion and co-operation with teachers, other learners and the professional community.
9. Track learner experiences and provides feedback for external or self-assessment.

These objectives were identified with the Stage 6 Science syllabus and the project objectives listed above in mind, but represent a good starting point for the development of any constructivist, learner centred teaching/learning material, irrespective of topic or mode of delivery. They are independent of any specific technology.

Contextualisation

Any constructivist teaching resource should deliver a strong context for learning. A learner should have an idea why an investigation is being performed, an understanding of the historical significance of the investigation, knowledge of the current applications and implications, and above all, should be interested in finding the result.

On the surface, however, there is an incompatibility between the educationally driven objective of strong contextualisation of content and the SCORM™ objective of reusability. The stronger the context, the less likely it is that the material can be used within other teaching/learning programs. *Technically* facilitating reuse is worthless unless the material *is educationally* reusable outside a single specific context.

To overcome this incompatibility a structure for the resource was developed that allowed for highly interactive Shareable Learning Objects with associated but independent contextualising elements. The result is that the activities themselves remain relatively context free. The rationale here is to produce Shareable Learning Objects that are as flexible as possible in terms of their reuse within other teaching/learning pathways.

The teaching/learning structure developed for the HSC Physics Virtual Laboratory pilot resource is hierarchical. It is made up of Modules, Sub-modules, Chapters, Shareable Learning Objects and Assets, along with linking Narrative Segments. The purpose of each element of the teaching map is outlined below.

- Modules define a broad content area and are taken directly from the structure of the syllabus. A module contains one or more sub-modules.
- Sub-modules define a narrower content area of physics investigation or knowledge and provide a context for learning related to that area. Sub-modules are taken directly from the syllabus and each sub-module contains one or more Chapters.
- A Chapter represent a collection of student outcome statements that have strong links and associations identified through analysis of the syllabus. Chapters do not correspond to any structure or level in the syllabus but were seen as being necessary in providing effective levels of context and navigation. A Chapter contains a collection of Sharable Learning Objects.

- Shareable Learning Objects are educationally self-contained elements designed to illuminate a single student outcome, or part thereof, from the syllabus. They provide learners with an environment that allows them to demonstrate achievement of the requirements of the student outcome. Shareable Learning Objects utilise one or more Assets.
- Assets are documents, web pages, databases, applets, media files or anything else that might be used within an educational resource that do not satisfy the requirements of being a Shareable Learning Object. Primarily, this would mean they have no specific associated trackable educational outcome.

The hierarchical structure also allows for the inclusion, at any level in the hierarchy, of Narrative Segments. Narrative Segments provide contextualisation for the Sharable Learning Objects that is outside any particular activity within the Objects. Narrative segments are used as introductions and conclusions to Sub-modules and Chapters as well as context bridges between the Sharable Learning Objects within a Chapter.

Narrative Segments provide historical, social and philosophical information. This helps students develop a coherent and holistic comprehension by identifying how the current material relates to other knowledge or understanding both within the field and across all sciences. It also allows the student to explore the applications and implications of the material within the broader society and to examine the roll within society of science itself.

Introduction and conclusion Narrative Segments are also used within Shareable Learning Objects to provide conceptual scaffolding. This is the background information required for a learner to have enough understanding of key concepts that the activities within the Shareable Learning Object are meaningful and illuminating.

In keeping with our aim of creating a resource with a constructivist focus, the contextual and conceptual Narrative Segments only deliver enough information to provide a context for learning and prepare the user conceptually for the activities within each Shareable Learning Object. They do not explicitly state any of the issues or concepts the activities are designed to illustrate or illuminate. This maximises the effectiveness of the ability of this resource to transfer knowledge through direct investigation and is consistent with the ordered list of product objectives above.

This separation of content and context must be carefully administered so as not to result in learning pathway discontinuities. The context should be continuous. Each element of the resource should address the questions raised by the last. The whole resource should tell a story of investigation, discovery and understanding.

The starting point for the development of a continuous and engaging context for sub-module 9.4.1 was the sub-module context statement "Increased understandings of cathode rays led to the development of television". This context statement, along with the analysis of the syllabus, suggested an historical context for the sub-module. The sub-module context statement provided in the syllabus is considered an integral aspect of both the new syllabus and, in turn, the HSC Physics Virtual Laboratory pilot product.

The contextualising Narrative Segments within the pilot resource have been created using Macromedia Director 8.0. A small and select library of images and audio are compiled as a shockwave. This allows for high quality audiovisual experiences that are small enough to be effectively distributed online. These audiovisual experiences are not video streams. This means they are not inherently linear.

This means that there is no defined next or last frame and even the state of each frame is initially undefined. Each audiovisual experience may have differences from viewing to viewing and the audiovisual experiences could be infinitely long even though they are built from a very finite amount of data.

Interactive Environments

Even when mindful that of educational methodology and not technical capability should be driving the development of educational resources, it is easy to overlook the distinction between an interactive *medium* and interactive *media*. There is a difference between technologies that have a non-linear navigation structure and educational content that is non-linear by nature. Both these things have advantages, but for different reasons.

A non-linear medium provides for ease, speed and flexibility of navigation through a resource. The word interactivity is often used to refer to this navigability. That is, a medium is referred to as interactive if the user has control over the path taken through the learning materials. While ease and speed of navigation is important, our position is that easy navigation and non-linearity of the medium do not constitute interactivity at the level, or of the type, required to satisfy the stated student outcomes of the HSC science syllabus.

The key to creating an environment that best allows a student to satisfy the requirements of this type of syllabus statement is interactivity with the media itself. The phrase "perform an investigation and gather first-hand information" implies an active roll for the student not only in getting to the experiment, but within it.

The HSC Physics Virtual Laboratory pilot project has developed educational media that fosters the development of sound conceptual understanding of physical principles through direct investigation. How can we make the claim of direct investigation? We've created simulated experiments that use photorealistic images that are controlled by the user down to the level of individual visual objects within single visual frames. This is interaction with the media itself. For each experiment, the user can vary any and all of the variables that affect the outcome of the experiment without any apparent quantisation of the audiovisual experience.

We create a photorealistic virtual world with a set of rules and a collection of objects, and the user investigates that world. Instead of having a video sequence of a falling apple, we create a virtual environment that contains an apple and the law of gravity. This represents truly virtual apparatus and experiments, as within the boundaries of the input variables and the programmed laws the state of the apparatus is unrestricted.

The physics syllabus lends itself to this approach, as most of the experiments and activities that need to be performed occur according to relatively simple, highly programmable, and well-understood mathematical formulae.

Not only is the particular audiovisual sequence experienced by a user unique and built in real time, but the frames which build the visual experiences do not pre-exist. The resource is creating the video images and the audiovisual sequence from a bank of elements according to the users input via algorithms that represent actual physical laws.

This means you can have as many input and output variables as you like, varied in any combination you like, at any point in the experiment, so long as the state of any visual phenomena can be represented by some combination of changes in the characteristics of a store of static visual elements. At the moment the characteristics that can be manipulated are the display transforms; hue, chrominance, luminance and opacity, as well as the linear transforms; transposition, rotation, elongation, and compression.

The range of characteristics that can be manipulated, when combined with the object oriented capabilities of new development software in Macromedia's Director 8.0, are sufficient to virtually re-create just about any mechanical system (and more).

The environments needed to be both visually and phenomenologically accurate. That is, both the appearance and the behaviour of the apparatus needed to be realistic. Thus, the simulated experiments use images of actual apparatus rather than the schematic animations and graphic representations commonly used in interactive multimedia.

This focus on replicating the real life experiment also needs to be taken into account when identifying the type of controls the user is given for an experiment. There are important skills involved in the accurate and effective manipulation of experimental apparatus. The controls displayed for the user should be as close as possible to those of the real apparatus, not just in terms of the functions the user *can* perform, but also in terms of functions the user *can't* perform.

There are many situations where the mode of delivery for the activities would allow for a functional set that wouldn't be available to the user if they were using real apparatus. A good example is ability to "jump" to points within an experiment by entering a set of variables. This function was discussed and would be easily implemented, but is counter to the principle of real life replication. It is important that the user develop the skills involved in using apparatus that is sometimes slow or difficult to control accurately.

This method of creating interactive media has two highly significant advantages over the use of a video stream; one related to educational effectiveness and the other related to flexible delivery.

Firstly, a video stream can only deliver a linear continuum of visual experience. This means that only one path through an experiment can be represented using video. The one-dimensional nature of a video stream means that the visual state of the experimental apparatus must be representable by a single valued function ($F: R^n \rightarrow R$). The experiment can have as many input and output variables as we like, but the observed phenomena must be able to be represented by a linear continuum. This is inadequate to recreate any but the simplest of experiments.

For example, if the position and colour of a visual element differed in response to two unrelated input variables, then in order to represent every combination of end visual states, a 2-dimensional video matrix would have to exist which houses a pre-existing video frame of the apparatus with the visual element at every possible combination of position and colour. We would have to develop video squared.

The second advantage is in file size. The entire self-contained file for the paddle wheel apparatus is 84k. It takes 10-15 seconds to download over a current standard Internet connection. A 3-minute video showing the experiment being performed, with exactly the same image quality, but half the frame rate (which is all most machines could currently deal with) and none of the interactivity would be around 25,000k and would take about 2 hours to download. This is a reduction in file size and required data rate of 3 orders of magnitude. The resulting shockwave is about 3 thousandths the size of an equivalent non-interactive video stream.

Instructions

A virtual collection of experimental apparatus does not make a Shareable Learning Object. In order for these interactive environments to become Sharable Learning Objects, they must have a demonstrable educational outcome. That is, there must be some requirement of the user.

Within the HSC Physics Virtual Laboratory pilot the activity requirements take the form of experiment instructions. These instructions are associated with an interactive environment and a range of other assets to build a Shareable Learning Object.

In order to facilitate an appropriate breadth and depth of instruction for learners with a broad range of abilities, a 2-dimensional instruction matrix has been developed. At any time, a learner can call for the next step of the instructions for an activity. This forms the first axis of the instruction matrix. Alternatively, a user can call for a more detailed description of the step they are currently undertaking. This second axis provides a stronger scaffold for students who require it.

The user-called instruction matrix combines with the conceptual and contextual framework of the narrative segments to provide a scaffold that is appropriate for the broadest possible range of users. This maximise the potential for developing conceptual understanding through direct investigation.

The resource doesn't require that any instruction be called for. If a user is able to perform an experiment or activity without utilising any instruction they may do so. As users gain skills, they will automatically remove scaffolding for themselves by not calling for the same breadth or depth of instructional support. The highly interactive nature of the media and the medium also promotes trial and error investigation as well as, or instead of, relying on instruction only.

Having the instructions given as audio as well as text allows a user to receive information without having to take their focus away from the experiment or activity being performed.

Lab book

As well as an experimental environment and instructions, there is one further requirement before the experiments can be considered appropriate Shareable Learning Objects. A Learning Object requires a *demonstrable* educational outcome. The resource must provide for functionality that allows an educational objective to be demonstrated.

For the types of activities and experiments prescribed in the Stage 6 physics syllabus, demonstration of the desired educational objective is often an experiment report. A student lab book was created to allow for the recording and analysis of experimental data.

The lab book is first and foremost, a formatted report of all the experiments a student has undertaken. If any instruction is given which requires the student to record information, an entry in the lab book is initiated. A user can also initiate an entry at any time to add to previous results or make a comment or note for later reference.

Data can also be sampled directly from the experiments where applicable but his functionality has been limited in its implementation for the following reason. As well as making sure a user had access to all the functionality required to demonstrate achievement of an outcome, it was important to make sure no functionality was provided that undermined a users ability to demonstrate a skill or item of understanding. Allowing users to directly sample data from an experiment environment was suggested as a potential general function for the resource. As the experiment environments themselves utilise a constant known set of variables, this function could have easily been implemented and on the surface it looked like a good use of the technology. On closer inspection, this function was revealed to undermine the skill development of the user, and was discarded.

For many of the Shareable Learning Objects, the report starts with a formal experimental log with aim, method, data, procedure, results, discussion, conclusion etc. For other Shareable Learning Objects the report might provide a template for an essay, short answers or a series of individual statements.

Along with this ability to record data, the lab book provides a range of analysis tools and techniques. Some of these tools are simply effective templates for the data gathered that aid conceptualisation, revision and discussion. More advanced tools include automatic graphing functions and excel-like table functions.

Support

Along with specific experiment instructions, there is a range of other support functions within the resource. The host application provides a highly graphical navigation function within the interface. Navigation is also available through dynamic, context specific contents and index pages. The resource also delivers a glossary and a full text search function. All these functions add to the end flexibility and usability of the resource and enhance a user's opportunity to be active in their own learning

As well as being able to be called for explicitly, all the reference and support functions are used within the resource. For example, all keywords within the text delivered to a user have hyperlinks to the glossary entry for the keyword. Rather than call for the glossary explicitly, a user can utilise the glossary function by simply clicking on a word that they want a definition for. This implicit system allows a user to selectively call for the reference information they require without having to divert completely from their primary experience or chosen learning pathway.

Each experiment or activity in the resource will also be linked to a context specific website. This site will provide a list of active links to related resources and information from educational institutions and industry. The website has the advantage of being updated easily to provide current and topical information and ongoing support without product re-publication.

The website will also provide environments for synchronous and asynchronous peer support and mentor support, with context specific chat rooms, notice boards and discussion or review questions. It could provide alternate teaching programs for the assets within the resource. For example, a server side teaching path could drive the assets of the resource to group the material according to associated skill area to deliver intensive experiences on particular skills.

The web site would also provide for direct assessment and feedback if the resource were used in conjunction with a course facilitator. For example, a users lab book could be submitted for marking. Facilities are being investigated that would allow a user to record all the parameters of an experiment and submit an "experiment timeline" via the web. Another student or a teacher could use this timeline to "replay" the entire experiment for comparison or assessment.

Host Application

All this material needs to come together to form a single functional educational resource. This requires a flexible and (as far as possible) universal application that can encompass and control a huge range of assets. We have chosen an XML back with a customised Internet Explorer front end. The hierarchical structure of the syllabus lends itself to XML, and the browser front end can display the various assets in a visually and functionally consistent environment with all the flexibility of the web.

The structure of the resource comes directly from a database (which itself was created to represent the structure and relationships of the syllabus) via a custom import to XML. The resulting XML document provides the skeleton of the resource and acts as the repository for the assets.

A significant body of information technology and data management has been developed for the pilot resource. Applications have been written to allow XML multimedia data to be manipulated and presented in a learner-friendly and teacher-friendly way, with maximum efficiency when the data come to be revised or repackaged. This technology is an essential foundation for satisfactory development of any modern multimedia product.

The independence of content and delivery allows for multiple teaching or learning paths and multiple user modes, both without asset duplication.

Conclusion

The pilot product developed demonstrates the potential for flexible delivery of educational resources. As well as utilising the effective delivery capabilities of new information technology, it uses new technologies and production methods to deliver specific educational objectives that are not achievable through traditional media platforms.

The product is consistent with the highest level of analysis of both the explicit and explicit content of the new syllabus, and is in line with current theories of teaching and learning.

The product implements the Sharable Content Object Reference Model (SCORM™) and delivers materials that are accessible, interoperable, durable and reusable. In particular, the open experiment environments, and the dissociation with any particular instruction, allows for the maximum reuse of all materials.

The interactive *media* within the Shareable Learning Object and the interactive *medium* provided by a proprietary host application will combine to give the teacher and learner unprecedented flexibility of, and accessibility to, primary experiences and takes the electronic delivery of learning into new technical and educational frontiers.