SCIENCE, E-LEARNING INTEROPERABILITY AND THE DISCOVERY LABORATORY MANAGEMENT SYSTEM

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ABSTRACT
Most universities and colleges within the UK use institutional or enterprise wide virtual learning environments (VLEs). VLEs can allow educators to create 'blended learning solutions' meaning information technology can be used to support traditional lecture based teaching. Some VLE systems can be considered to be difficult to use, an attribute that is primarily attributed to their size and sophistication. To use them successfully, an institution usually requires dedicated support staff. This paper presents a laboratory based science e-learning system called Discovery Lab Manager. The DLM is an e-learning system which contains some of the features of a VLE but allows tutor near real-time control of what learning material is available to a small group of students. Issues surrounding e-learning software interoperability are presented alongside issues of usability. Whilst enterprise-level VLE systems do have a place within an institution, a case can also be made for smaller more focussed system.

KEYWORDS
E-learning standards, interoperability, virtual learning environment, managed learning environment, engineering education

INTRODUCTION

Enterprise level virtual learning environments appear to have been adopted within a large proportion of further and higher education institutions within the UK (see Powell & Davis, 2001). VLE systems allow tutors from any discipline to easily disseminate learning materials to students quickly and efficiently.

This paper presents two concepts that are related to the use of VLE systems. The first concept explored is interoperability. A number of emerging interoperability standards which allow learning material to be exchanged between different learning systems is presented. The second concept is a variation to what could be considered to be a traditional VLE : a simpler, lightweight laboratory management system called the Discovery Lab Manager, a system designed especially to aid and enhance science and engineering education.

E-learning standards are continually evolving. The penultimate section describes how e-learning interoperability standards may evolve and how their importance may grow as they become more defined and accepted by e-learning solution vendors. Finally, a summary of the key issues is given.

ENTERPRISE LEARNING ENVIRONMENTS

A virtual learning environment, known by the abbreviation VLE (sometimes known as a MLE or Managed Learning Environment) is often understood to be an institution wide portal which allows students access to information that is directly relevant to a course or a series of courses which a student attends.

A VLE can provide students with a wide range of digital resources, ranging from copies of PowerPoint presentations which were delivered by lecturers, associated sets of reading lists in the form of PDF or word processing documents and video clips. Some VLE systems also provide formative and summative assessment capabilities. Computer presented assessments are usually multiple choice questions or 'fill in the blank' templates. In some cases VLE systems also provide tutors with the ability to capture and organise students' assignment submissions.

A VLE allows tutors to add and remove students to a course, and change what material a group of students may have access. Providing additional learning material outside of the usual lecture hours is one of the central concepts behind the term 'blended learning', an issue that is addressed in a previous CBLIS paper (see Andrew, 2003; Whitelock & Jelfs, 2003). This is understood to mean student oriented learning where face to face teaching is assisted by the use of information technology. Some VLE systems allow learning material to be uploaded and then released on particular dates as a period of lectures proceeds. A tutor may request that students become familiar with a certain concept before attending a lecture and provide access to previously presented material when a lecture has finished.

Some VLE systems are also supplied with content authoring tools allowing custom on-line courses to be constructed. Providing complementary courses and advertising their availability on an institution VLE can provide the student with the capability to fill the gaps in his or her knowledge if certain topics were unclear during lecture periods. Of course, constructing whole courses is expensive in terms of time and money. Sets of pre-written courses exist which can be loaded into a VLE.

With every form of technology, there are, of course disadvantages. Firstly, there is the issue of cost. VLE systems from the main vendors are often very expensive. Users are sometimes committed to taking a support package which adds additional cost. In some cases, institutions have avoided the costs inherent in commercial packages by opting for an open-source equivalent. Commercial packages provide customers with a structured support system, whereas open source alternatives sometimes demand a higher level of knowledge and administrative expertise.

If a VLE is used throughout the whole of an educational institution, it is likely to be administered through a central support department. Subsequently, this adds a level of bureaucracy, an issue with which current educators are continually faced. Finally, due to the sophistication of VLE systems they may not lend themselves for use amongst small groups of students – they are designed to cater for a large user base.

E-LEARNING SOFTWARE INTEROPERABILITY STANDARDS

Consider the scenario where an institution has decided to commit to a particular VLE system. Several years later, the vendor chooses to change the licensing policy and now requires that an institution pays an increasing licence fee every year. Faced with budgetary constraints an institution may decide to investigate alternative VLE vendors, including potential solutions from the open source community. Suppose a cheaper alternative *is* found, one which provides a similar level of functionality. Now the question must be asked – is it possible to migrate the student and course records from the current system to the new system? This is one of the many issues that have driven the development of e-learning interoperability standards.

It is in a software vendors interest to develop an entirely proprietary solution since this locks in the user to their own approach, ensuring a continual revenue. It is not in the best interests of vendors to develop a solution that works with other systems. The software vendor is interested in developing software features that users desire and will find useful, since they can charge a premium for these. To ensure that customers get the best deal, it is in the users best interest to ask for software systems that *are* interoperable with others.

In web-based systems, the most obvious element of software that could potentially be moved between systems is the web page. A web page can contain graphics, demonstrations, video clips, sets of questions and also, as will be presented later, allow real-time measurements to be taken. Moving a set of web-pages from one server to another is a little more difficult than it sounds. A page may contain sets of link to other web pages within the same system, a mechanism to write records to a database to indicate page access or to store activity state, or to hold the results of question responses in preparation for review by a tutor.

Some key questions regarding e-learning interoperability include:

- How can I move sets of web pages between different systems?
- Is there a way to move sets of students from one system to another?
- How can I associate learning material to a 'course'?
- Is there a common way to define a 'group' of students?
- How can I give a set of students some tests to perform?
- How can a system store learning activity 'state'?
- How can I search for learning resources that suit my needs?

E-learning software interoperability is an issue that is has received a significant amount of attention through organisations such as ADL[1] and IMS. IMS is the name of an organisation that is becoming the custodian of e-learning interoperability standards. IMS, formerly known as 'instructional management system' is a consortium of non-profit organisations such as universities or governmental bodies and commercial companies[2].

IMS has published a large number of what is known as interoperability specifications. These specifications have been until recently a set of XML data structures. More recently, IMS has been moving towards publishing API specifications in the form of web-service descriptions, which will conceptually allow different types of system to communicate together.

IMS bears some relationship to another initiative, called the Open Knowledge Initiative or OKI, Originating from MIT, the OKI project publishes a range of API specifications which can be implemented by a solution provider[3]. The IMS and OKI projects are different, yet complementary. IMS primarily describes data structures, whereas the OKI project primarily describe APIs.

Some IMS specifications have an intimate relationship to an initiative called SCORM. This is an abbreviation of Shareable Content Object Repository Model[4]. Developed as a collaboration between the US government, industry and academia, the SCORM standard defines a set of functions which web pages can call to indicate whether the page has been loaded, or unloaded, and values allow students 'learning state' is remembered between learning sessions. Theoretically a SCORM e-learning package developed on one system can be utilised by a different system. SCORM uses something called the IMS Content Packaging specification (Smythe, 2004a).

The IMS Content Packaging Specification allows learning material to be stored in a prescribed format allowing material to be moved to other systems. In essence, the content package is a compressed zip file that contains a set of *self contained* web pages which means that they do not reference any other pages in any other content package. These web pages and the resources that they use, such as graphics or animation, are described in a 'table of content' file known as a XML manifest file.

The table of contents manifest file can also contain data described by other IMS Specifications. The metadata specifications, (see Barker, 2004) describes a set of data structures that allows a content

[1] ADL is an abbreviation of Advanced Distributed Learning, see http://www.adlnet.org/
[2] More information about the IMS project can be found by visiting the IMS website: http://www.imsproject.org
[3] The OKI initiative can be found at the website: http://www.okiproject.org/
[4] More information about the SCORM project can be found by visiting the ADL website

author to 'describe' a content package. Using the metadata structures, an author can title a content package (also known as a learning object), assign a simple description, assign a set of classification categories (such as dewey decimal or library or congress) and a number of relevant keywords. Using this information, a tutor can 'search' for content within a VLE in a way that is similar to earlier learning repositories such as MERLOT[5]. There is subsequently the beginning of an IMS repository interoperability specification, which allows different sources of learning material to be searched from a single system.

Moving content from one system to another is only one element of the interoperability jigsaw. IMS have also published the Enterprise specifications (Smythe, 2002a). This describes data structures that can be used to import and export student and group information between systems. Recently, a set of web services have been defined and sample implementations developed showing how the specifications can be realised (Smythe, 2004b).

Another central specification is QTI. QTI, an abbreviation of Question and Test Interoperability, defines an XML document that can describe a number of questions which can be understood by a VLE system (Smythe, 2002b). The specification describes in detail a number of different types of question such as multiple choice, multiple selection and fill in the blank. The specification also makes provision for more sophisticated interactions utilising Java applets as the user interface mechanism.

Like content packaging, QTI is one of the more mature specifications and has been adopted by a number of content vendors. Subsequently a number of question authoring tools have appeared on the market. QTI only describes how to describe questions. It does not describe what to do with the results when a question has been answered.

Another interesting specification is simple sequencing specification. The 'simple' part of the title does not refer to the fact that the specification is easy to understand. Instead it refers to the idea that simple learning objects can be joined together to form alternative paths or sequences through a series of learning objects. Simple sequencing allows a VLE or MLE to become adaptive, to change what learning material is presented to a student as they progress. If it is discovered that they do not have sufficient strengths in one area the system may present a set a remedial learning objects. There are other specification initiatives regarding the definition of interchangeable competencies, reading list, learning design and the new concept of an electronic 'learner portfolio' (See Hummel, et. al., 2004).

DISCOVERY LAB MANAGER

The Discovery Lab Manager (DLM) is a standards-based computer based training system that delivers science and engineering computer based training software within the bounds of a single laboratory or group of laboratories. The DLM contains some of the features of an enterprise level VLE[6] but has been designed to be applied and used for small groups of students.

Science and engineering concepts are often taught within schools and universities using hardware available from a custom laboratory. The DLM is designed to deliver CBT packages that are to be used in association with hardware found within a specific laboratory. The DLM was initially designed to help and educator to demonstrate the principles of electrical science, process control, digital systems and telecommunications. An earlier version of the system was described in an earlier CBLIS paper (Douce & King, 2001).

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[5] MERLOT, a website previously discussed at CBLIS is a repository of learning materials available for use by educators. The corresponding website is: http://www.merlot.org It is interesting to note that both the main VLE vendors, Blackboard and WebCT have announced features that allow tutors to easily integrate MERLOT content into their systems.

[6] More information about the Discovery Lab Manager can be found at: http://www.fbk.com/e-learning/discovery-lab-manager.asp

The success of a lesson depends partially on organisation as well as educational skills. The motivations behind the DLM are primarily:

- To deliver appropriate learning material to a student or a group of students that allows the laboratory equipment to be utilised in a cost effective and efficient manner, presenting the appropriate software required by both student and tutor.
- To deliver appropriate evaluative tests allowing the tutor to gain an immediate insight as to whether the students or group of students have understood the concepts that the equipment has been designed to demonstrate.

It was decided to develop a new delivery system since:

- Existing VLE systems cannot easily present content for short laboratory sessions since the selection of appropriate material can be time consuming.
- Existing VLE systems are very expensive
- A VLE is often under the control of central IT services, a smaller system can empower the tutors.

A central requirement was that the DLM be as interoperable as possible, utilising as many of the emerging interoperable specifications as possible.

DISCOVERY LAB MANAGER COMPONENTS

The laboratory management system comprises of a tutor management component, a student content presentation system and a QTI testing engine. Theses components allows tutors to quickly and efficiently build custom courses by performing simple textual searches against a repository containing learning objects associated to the learning packages and the available teaching equipment.

Figure 1. The DLM Management Application

In a blended learning scenario a tutor would deliver a class to present a particular topic. When instructed, the students would utilise the CBT software to gain access to the learning objects that were directly relevant to a particular lesson, enabling the students to use their laboratory hardware. A tutor can construct custom modules (or classes) quickly and efficiently. If a tutor wished to find out what pieces of equipment could be used to demonstrate the principles of ohm's law or the principles of voltage and current, these terms could be entered into the repository manager. The resulting objects could then be selected and delivered to a particular group of students. During a class, if it becomes apparent that students are having problems with particular concepts the tutor can quickly change the teaching direction by assign different learning objects (with different learning objectives) to different groups.

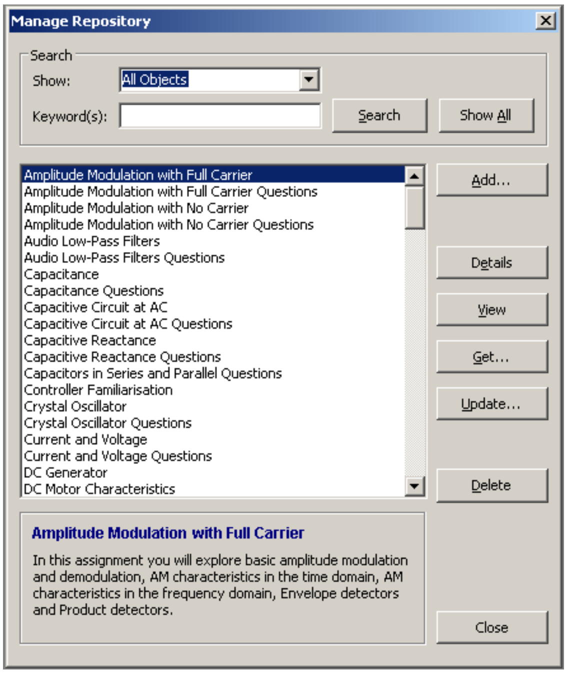

Figure 2. DLM Repository Manager

Figure 2 presents the repository management tool, showing all learning objects within the system which utilise the IMS metadata and content packaging standards. The screen contains the buttons ‘update’ and ‘get’. These allow individual objects to be retrieved from the repository and placed on a local machine. When outside of the DLM system, providing that a VLE supports the same standards, the learning objects can be moved to a different system.

Learning objects are of two types – instructional objects and question objects. Instructional objects comprise entirely of learning material, such as text, graphics and interactive applets. Question objects, implemented using the IMS content packaging and QTI standards allow simple topic specific tests to be given to students.

Students and groups can be easily managed using the group and student management elements. Using a simple set of dialogs, tutors can add new students to the system, allocate them to groups and assign the groups to modules. The DLM also contains a simple and easy to use reporting mechanism that allows student results to be viewed. The reports can be exported into PDF, saved as word processing or spreadsheet documents. To assist in teaching sessions, clicking on a report hyperlink will take a tutor directly to the QTI-based questions which were administered to the student.

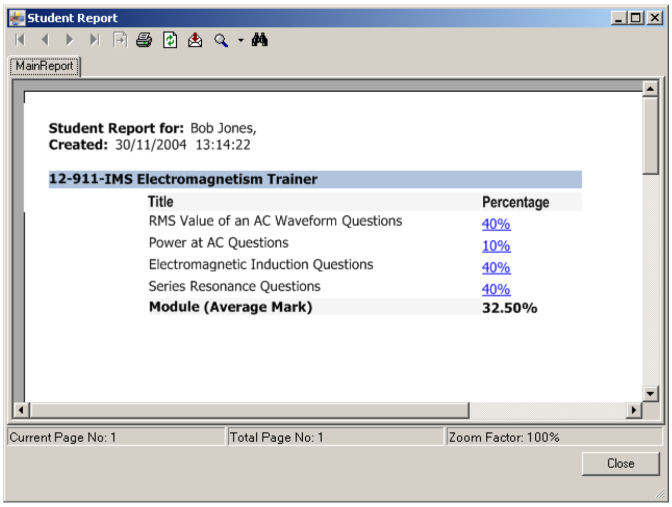

Figure 3. Screen from the Reporting Component

The student access the learning package software through a normal web browser. Unlike other VLE/MLE systems, the tutor does not use a web-based interface, but a simple and easy to use GUI application which interacts directly with the server, shown in Figure 1. Using a GUI rather than a web application provides the user with a more sophisticated user interface.

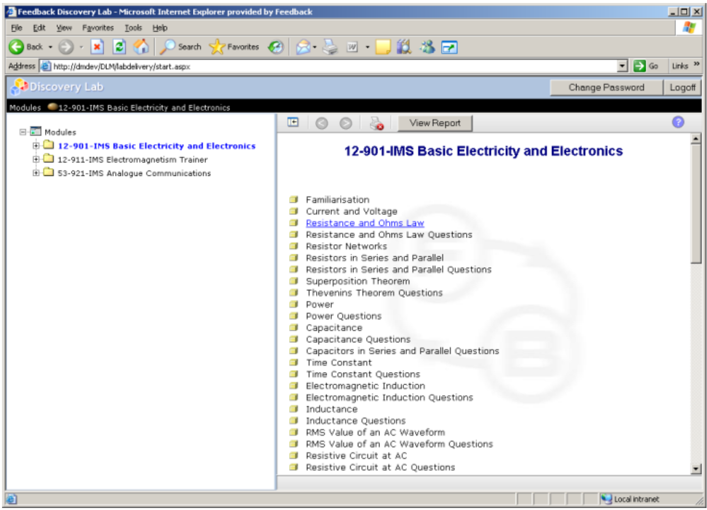

Figure 4. Web browser display of an entire learning package

Particular attention has been given towards the installation of the system. The DLM is provided on a single CD-ROM. This is substantially different to other VLE providers who insist that providers either use a service that is externally hosted, or a system that has been supplied pre-configured with all appropriate software or commissioned by a consulting engineer. A key requirement was that the DLM system should be installable by the educators themselves, rather than relying on a central IT services.

DISCOVERY LAB MANAGER PACKAGES

Feedback Instruments manufactures teaching equipment to teach a wide range of engineering topics. For each hardware range there is usually a corresponding e-learning package. In some cases, the software is central to the operation of the hardware, since the software takes key measurements during the operation of the hardware enabling invisible concepts that the hardware illustrates become visible to the student.

Feedback Instruments has just completed developing their third generation of CBT packages. The first generation utilised MS-DOS, presenting real-time measurement systems alongside explanatory graphical displays and explanatory text encoded using a propitiatory mark-up language. The second generation saw the conversion of the e-learning content into a HTML based format and allowed real time measurements from physical hardware to be taken using Java applets. The third and current generation is standards based. The existing learning material has been converted into a large number of discrete IMS content packages.

A typical CBT package contains a series of twenty or more individual content packages or learning objects. Each learning object has been tagged according to the IMS Metadata specification. An object is conceptually a Feedback Instruments assignment. An assignment comprises a series of practical activities, such as connecting an electrical circuit in a particular configuration and taking a set of related measurements.

A learning object may also contain a set of essay questions which can be either printed out or stored externally, a series of explanatory graphics, instructions on how to prepare for an experiment and in some cases some empty spreadsheet templates ready to collect results. A spreadsheet template, for example, may be designed to show current and voltage thus helping the student to understand Ohm's law.

Packages explore the principles of servo mechanisms, process control (temperature, level, flow, pressure and acidity) and electrical motors (power and machines). All the software needed to perform real-time measurement is provided within each content package.

FUTURE DEVELOPMENTS

At present, the acceptance and use of the interoperability specifications amongst various VLE systems is varied. The IMS content packaging specification is increasingly being adopted in various forms since it provides a simple and elegant solution to the problem of moving web content between different systems. More debate surrounds the use of the metadata standards and how they can be adequately used and adopted (Currier et. al., 2003 & 2004).

One of the most significant areas of change within the IMS specifications lies in the areas of the QTI specifications. An internal evaluation of a number of different QTI authoring tools indicated that each adopt a slightly different approach the implementing the specifications. This meant that one set of questions authored with one system may not be able to be authored in another. This is in part due to the way that the specification is described. The second version of the QTI specification aims to alleviate some of these problems by being more prescriptive in the way that it should be used.

Specification ambiguities have not prevented the development of successful learning systems. Different solution vendors, sometimes working in co-operation have constructed working solutions allowing tutors to administer on-line tests. Examples being Blackboard and QuestionMark[7]. Only by building a real system can the completeness of the interoperability specifications be fully evaluated.

Success of some of the specifications may eventually boil down to how useful they are in practice. Authoring tools and repository searching mechanisms may have to change in response to how educators wish to use them in educational scenarios. It may also transpire that the simple sequencing specification is too complex to be adopted easily. Constructing paths through learning environments is considered to be almost a 'programming' activity, and something that takes considerable time. Alternatively, a commercial entity may propose a solution that enables the specification to become an essential component of a VLE offering.

[7] QuestionMark is an organisation that develops software solutions that allow sets of questions to be authored using a question editor. Other products allow tests to be administered to students. QuestionMark Perception, the question authoring tool was a topic of a workshop in CBLIS 2003.

Further work is required to extend how the DLM currently uses the emerging interoperability standards. The IMS Enterprise specifications which allow movement of registration information from one system to another may prove to be significant. It is essential that any new developments in standards are considered in turn since they are likely to be of interest to educators as they try to ensure maximum return in their investment. It is essential that the DLM system works with a wide range of content authoring tools, such as those provided by the UK JISC e-learning framework[8].

CONCLUSIONS

This paper presents a number of increasingly useful e-learning interoperability standards which are expected to grow in importance as they are more widely used by both educators and commercial systems providers.

Virtual learning environment systems are large systems often catering for a whole organisation or institution. Since they support a large number of students they may be perceived as complicated and expensive, both to maintain and manage. The term VLE is often used in association with the term ‘blended learning’, the belief that technology should be used in association with more traditional teaching approaches.

Science and technology is often taught in a laboratory environment where instruments and measurement devices are used often amongst small groups of students. Engineering education requires students to interact not only with real physical hardware but also with each other. In situations where application software is required to be delivered quickly and efficiently in response to the changing dynamics within a class, a large heavy weight virtual learning environment which comprises time tabling and external messaging facilities in some situations does not seem to be entirely suitable.

The Discovery Lab Manager system is a standards-based system which aims to give tutors and educators the power to run their own managed learning system specific to their very own laboratory environment. The DLM system is not intended to compete with VLE systems but instead provides an easy to use windows-based mechanism that allows relevant to material and software to be disseminated to different groups of students quickly and efficiently.

E-learning interoperability is a fascinating topic. Just as HTML has become the de facto standard in terms of web presentation, it is expected that other standards will emerge to enable educational materials to be shared between educators and educational systems. The content and e-learning software used as a part of the DLM system is intended to be reusable as possible, given current standards, enabling the educators to make the final choice in how they wish to use the learning material that they have access to.

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[8] See www.reload.ac.uk, which describes a simple content packaging tool which can be used with a number of different VLE systems.

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