Open, Dynamic Content and e-Learning Management Infrastructure for Engineering and Natural Sciences

John B. Stav[1] and Hariklia Tsalapatas[2]
[1]Sor-Trondelag University College, Trondheim, Norway
[2]University of Thessaly, Volos, Greece
john.b.stav@iaf.hist.no
htsalapa@uth.gr

Abstract: NS-eCMS is developing an open web-based content management, communication, and collaboration eLearning platform that addresses the specialized requirements for distance education in natural sciences. The federated architecture enables straightforward development, exchange, and publication of material through open standards like XML/MathML. The system will provide an open communication platform for dynamical information exchange and management in a pedagogical framework. Time effective communication during the educational process for undergraduate learners and under-graduate academic institutions, is obtained by exploring new interfaces as light pens and electronic blackboards.

Keywords: distance education, e-Learning, content management, learning management, mathematics, physics, natural sciences, engineering, XML, MathML,

1. Introduction

Distance education programs on natural sciences combining asynchronous e-Learning with synchronous AV-learning have been used with success in recent years. Universities use new developments such as live-sized multi-point videoconferencing over IP with integrated AV and data environments, such as shared applications and Smartboard technology, with great success to incorporate distance learning into their ordinary on-campus programs (sebra 2003). However, although both asynchronous e-Learning overcomes geographical and temporal constraints transforming learning into a process that can occur at the independently determined convenience of instructor and learner (Harris D., DiPabolo A., Goodmann J., 1994), asynchronous e-Learning is recently being used as a complementary educational tool in traditional classroom education (e-Learning 2001), demand has been developing for asynchronous and synchronous authoring, presentation, and collaboration tools that promote use of standard mathematical and scientific notation. The Xmath project (Xmath 2001) was one of the first projects addressing such topics in mathematical education. Such tools must overcome the increased requirements for time-effective and interactive communication during the educational process enabling efficient interaction among administrators, educators, learners, and researchers through the exchange of media rich documents containing information in a standard format. The typical content of such documents are text based material supported with formulas, graphs, sketches, animations, (interactive) simulations and support for online calculation through Computer Algebra Systems (CAS) in sophisticated combinations.

Vendors of Commercial e-Learning Distance Learning Platforms have not supported dynamic representation of standard mathematical and scientific notation because distance learning on most generic subjects have not required it. On the other hand, lack of standard mathematical and scientific notation and simple integration of, for instance sketches and drawings that are imperative, have limited the utility of distance learning whenever there is a strong technical component in the educational material.

Engineering educational programs at graduate level use a wealth of new, advanced, and standalone scientific calculation and construction tools, while typically many students at the undergraduate level hesitate to use advanced software tools due to time limitations related to heavy academic schedules and a limited number of available computers at the universities. During the last couple of years have several advanced commercial CAS introduced web-based learning alternatives. The last version of the scientific calculation tool Maple (Maple 2003) offers for instance mechanisms for direct publication of scientific content on Web. Such advanced calculation tools have traditionally been tailored to a large extent to research oriented development at a graduate or higher level, and they use as a rule their own information representation. The existing solutions are characterized by lack of integration with a learning and/or content management infrastructure, whereby these systems work best as standalone courseware

management tools for scientific computations. As a result, CAS constitute useful tools but not complete solutions for undergraduate distance learning programs in natural sciences.

Commercial Courseware Management Systems (CCMS) have during the last year evolved significantly through the emerging open XML standard. CCMS such as Blackboard® (Blackboard 2003) and WebCT (WebCT 2003) will soon integrate MapleNET (MapleNET 2003, sebra 2003) content ranging from links to fully integrated features through dedicated windows applications like Maplets. Open courseware and MapleTA (Maple 2003), a web-based assessment system, are expected to work similarly. WebMathematica (Wolfram 2003) supports the addition of interactive calculations and visualization to a website by integrating *Mathematica*, the world leading competitor to Maple, with the latest web server technology and server based computation. These CCMS claim at the "shipping level" to address a range of explorative working methods by providing web extensions for the use of standard mathematical and scientific notation, the inclusion of scientific calculation tools, and Open courseware delivery.

However, there are several unsolved questions for their appropriateness to natural science education in general and to the usefulness and importance of such tools in distance teaching at undergraduate level in particular. It is for instance not quite clear how numerous standalone scientific calculation and construction tools, which indeed uses their own information representation, are going to interfere with the open XML standard for information representation, including delivery, exchange, up- and downloading of documents. Of particular interest are the new frameworks for separation of concerns and component-based web development.

It becomes apparent that institutions in Europe have been often forced to use unsuited tools and web solutions in an effort to upgrade content that contains natural sciences and engineering components. This practice highlights the need for an educational service for natural sciences that addresses all aspects of the educational process from entering media rich data in a time efficient way for both learners, teachers and tutors, including mathematical formulas, graphs and sketches/drawings into the system, educational content management, exchange and retrieval of learning material through international standard formats, inclusion of scientific computations, and learner knowledge assessment. Standardization and system interoperability with present and forthcoming e-Learning portal initiatives, and existing Learning Management infrastructures, are desired.

The NS-eCMS project, which is partly founded by the Socrates–Minerva programme in the period 2003-2005, is designing and implementing an open web-based content management, communication, and collaboration e-Learning service that addresses the specialized requirements for distributed distance education in natural sciences. The system will be an extension of the existing web based eCMS federated content managements system for support of distributed teaching, founded by the European Commission's Minerva-Socrates program in the period 2001-2003. Media rich content management will be achieved through a federated architecture enabling straightforward development, exchange and publication using international standards, specifically XML and MathML. The proposed infrastructure will support the integration and interaction with mathematical tools for the execution of computations. Additional user interfaces, e.g. light pens and electronic blackboards that facilitate time efficient interaction with the system for various user groups, will be explored.

The proposed system will mainly benefit undergraduate learners and undergraduate academic institutions involved in natural science teaching/instruction by providing services that addresses the entire educational process in natural sciences, from information exchange to information management.

2. The basic features of the NS-eCMS infrastructure

The 5 partner institutions in the project (NS-eCMS 2003) have complementary experiences from net based learning activities at university level, as well as from national and international collaboration. From previous projects the partners knew that joint ventures between traditional universities and net-based collaboration, are possible at national and at limited international levels. The current project aims at extending these activities to a Pan-European level, establishing it with a true European dimension. Concentration of the content to natural science related services implies an implicit contribution to the ICT

literacy and exploitation of technology and services adopted to technical education and amongst the general public. The dissemination is going to focus on joint efforts and collaboration to create a European network for higher technical and scientific education, applying experiences and findings from this and previous work.

NS-eCMS aims at supporting distance learning of undergraduate learners by providing an open communication platform for dynamical information exchange and management in a pedagogical framework. The communication system (Stav J. B. and Tsalapatas H 2004) handles rich multimedia content and offers interfaces containing tools for online execution of computations, plotting, online examinations, and tests. The system supports time efficient interaction through light pens, electronic blackboards, tablet PCs, etc. Mathematical objects are exchangeable from the web interface to MathML standardized supporting tools and editors.

Component based web development involve four concern areas for a successful web-presentation, i.e. production of content using open standards like XML, inclusion of external calculation tools through application logic, design of various presentation styles which easily could be adapted for various web-environments, and presentation of the complete learning material on web. Such a selection will remove the historical troublesome contract between application logic and presentation (Apache Cocon 2003).
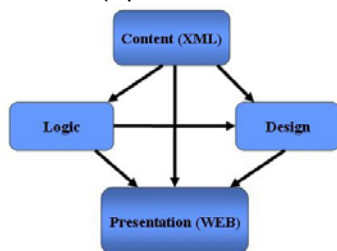

Figure 1: Separation of the four concern areas

As shown in figure 1, the NS-eCMS services will separate XML based content from application logic and design of the web presentation. These challenging areas involve various topics like MathML, standard mathematical scientific notation, Chemical Markup Language (CML), Scalable Vector Graphics (SVG), educational content metadata descriptions, and for instance the Maple 9.0 XML tools package which is updated with significant new functionality including namespace support, XSL transforms (XSLT) and a validating XML parser.

Figure 2 displays how MathML standardized web output can be transferred from the web page into a MathML supporting editor. For instance might a web-page provide an advanced calculator (CAS systems) giving the results in standardized MathML format. Mathematical interactive tests can through MapleTA be provided online with automatic grading of results. The teacher submits and exchange content with the eCMS system through a standardized format. The student will interact with course modules which might interact with various services like MapleNET, MapleTA, eCMS etc.

Figure 2: Basic overview of the NS-eCMS functionality, and the location of the previous eCMS system.

Use of XML based technology ensures that the course material, i.e. learning objects, might be adapted to future needs, as XML is well adapted for database transformations to new standards. This includes for instance simple adjustment to new ICT solutions that will emerge and new design of web pages and course management systems. A knowledge base containing XML documents might be recycled into new presentations by using XSL transformations (XSLT).

The main outcome is going to be services offering time efficient mechanisms for communication in distributed distance teaching of natural sciences. The services and system will be evaluated through user trials and courses. Feedback from internal and external groups of students will evaluate the quality and relevance of the services.

3. Objectives for the NS-eCMS services

The project vision is the design and development of an adapted open web-based content management, communication, and collaboration infrastructure for the support of eLearning of natural sciences, which will make these fields more attractive to a broader

undergraduate student population. The infrastructure to be developed is going to address all aspects of the learning process on natural sciences from introducing information into the system, including dynamical representation of mathematical formulas and easy implementation of hand made sketches/drawings, which are imperative in natural sciences. Moreover, the dedicated infrastructure will contain features for managing the educational content, facilitating the educational process through effective communication and collaboration, executing computations on-line, and assessing learner knowledge through exercises, tests and examinations.

The specific objectives of the system are

- Single point of access to possibly distributed content and services including compatibility with present or forthcoming eLearning initiatives, for administrators, learners and content providers.

- Efficient educational content management, emphasizing use of standard mathematical formalism in natural sciences and internal information representation using open standards like XML and MathML.

- Flexible internal representation of content (XML and MathML) that can be transformed to several existing and forthcoming formats. User interfaces enabling easy introduction of elements related to the teaching of natural sciences, including mathematical formulas, graphs and sketches/drawings, into the system. Multiple interaction methods will be explored, including web technology, light pens, electronic blackboards and digital document cameras.

- Integration of mathematical software tools (CAS servers) for on-line execution of computations and visualization of results, and integration of legacy code developed at the participating institutions will be explored as proof of concept.

- Minimal requirements for installation of client tools. Services for the support of cheap online web-solutions for large groups of learners based on the above-mentioned infrastructure. Services to be implemented include on-line learner assessment through examinations and exercises.

- Efficient collaboration and communication that facilitates the learning process through asynchronous tools (chat-rooms, forums, collaborative space sharing) and synchronous applications as video-conferencing through desktop units.

- Online structured course development and editing. Organized state of the art educational content for natural sciences that takes advantage of the proposed infrastructure and MathML for effective information presentation.

- Autonomy of providers through distribution of material and metadata descriptions.

4. Envisaged results and outputs

The project aims at a federated, distributed organization of content provided by educational institutions across Europe. The challenge is going to be to cover all aspects of the eLearning process in those fields, from the introduction of information into the system, to the management of the information (publication, dissemination, discovery, retrieval, presentation, indexing, etc), to the execution of computations required by the educational process. This infrastructure will ensure autonomy to content contributors and it will be transparent to learners, who will have access to the system, services, and content through a single point.

Specifically, the following outputs are envisaged

- The adaptation of an existing eCMS content management infrastructure

- Development of a limited amount of educational content material for natural sciences by using international standards, specifically XML and MathML, and implementation of MapleNet. MathML will be used for the internal representation of mathematical formulas to ensure compatibility with other (forthcoming) initiatives and tools.

- A straightforward user interface enabling easy introduction of elements related to the teaching of natural sciences, including mathematical formulas, graphs, and sketches/drawings, into the system.

- Integration of external mathematical tools for the execution of computations.

- Assessment tools and services

- Reports on system design, implementation and evaluation.

- The above will result into a repository of services and content for eLearning on natural sciences. Access to the repository will be provided through a single-point of access portal. New developments will be achieved through open-source tools to

ensure cost effectiveness in the mass deployment of the services.

Figure 3 outlines a high level overview of the NS-eCMS system and services to be developed. The existing eCMS infrastructure (Tsalapata H., Stav J., Brna P., Kalantzis C., 2003), which will be adapted and extended with new services for the needs of this project, is displayed on figure 1. Additional information can be found which provide more details and key features of eCMS services can be found in the eCMS Design and Implementation Reports (Tsalapata H., Brna P., Stav J.; Tsalapata H., Kalantzis C., Brna P., Stav J., 2003). The existing eCMS metadata and content repositories will be redesigned to take advantage of XML and MathML technology. Furthermore, the examinations databases and services will be upgraded to support MathML as well as random question generation. The statistics database will be updated to hold and analyse additional information as necessary. Additional services and interfaces will be implemented as displayed.
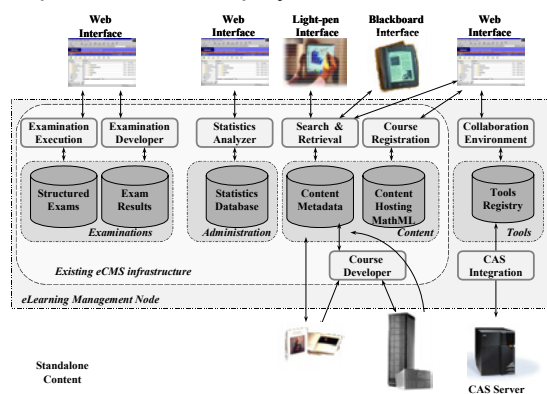

Figure 3: The NS-eCMS system architecture

Users are going to interact with the NS-eCMS Content Learning Management services through a web-based interface providing customized library views targeting the needs of learners, content providers, course managers, and repository administrators.

The integrated metadata scheme take into account earlier work in this area (The Dublin Core), (ETB), (Learning Technology Standards Committee 2000), (Nikolaou C., Georgakopoulos G., Tsalapatas H., 2000) and (eCMS 2001).

5. Pedagogical and didactical approaches in natural sciences

Teaching of natural sciences have - more or less independently of ICT developments - always called attention to a wider context of the educational process by maintaining two crucial topics:

- To train students in logical and abstract thinking
- To build up physical comprehension by applying mathematical knowledge to all types of natural sciences and engineering fields.

However, advanced scientific calculation and constructions tools have been developed over the last few years. They easily do tedious work calculations in a second and extend continuously the physical limits and barriers of complex problem solving in research. They have in a sense have achieved status as "generic public property" in engineering and natural science education at higher university level.

Nevertheless, from a historical point of view have students usually obtained a significant part of such qualifications and experience by doing a tremendous amount of (tedious) work, exercises, and projects by hand in order to drill use of exact notation and unambiguous communication which are generic for natural sciences. In the academic communities, lessons on traditional blackboards and various amounts of deep and/or formal exercise solving on paper, partly through the help of calculators and computers, are still going to be important basic components in the daily life for an undergraduate student in the forthcoming years. Both these old European traditions, which call attention to a wider context of the educational process than the final examination, and the natural requirements for exact and unambiguous communication are going to be the premise provider for the pedagogical goals of successful distance eLearning programs of natural sciences. The communication and collaboration environment proposed in this project would address these challenges more effectively than existing solutions.

The project is not primarily aimed at development of new pedagogical and didactical models. It will instead use existing models for learning environment tools used in ODL which usually provide four main areas, presentation-/lecture area, working area, knowledge-area and private area (Haugen H., Ask B. and Hjeltnes T. , 2002), and direct its actions more towards the organisation dynamics that apply for previously obtained results in natural sciences, i.e. by establishing bridges between the old teaching traditions and the new flexible interactive features. The project intends to turn the student into a "player" with dynamical natural science expressions, rather that he should act as passive viewer. It should as well at the same

time stimulate the teacher to act more as an instructor that has the ability to monitor students working though the distance learning services in a host of new ways, i.e. through various mechanisms connected with student-student, student-teacher, and teacher-teacher communication. Services that support learners, teachers, and course organizers to retrieve previous course material, structure new educational material, and deliver high quality communication support (assessment, feedback, discussions, and course management) are going to be of particular interest of those pursuing *e*Learning of natural sciences. State of the art methods and systems will be applied, in line with the experiences at the partner institutions. Special attention must be given to stable and scalable uploading and downloading of content, which should be represented in a standard format, selection of time efficient formula editors and online distribution through high quality videoconferencing in distance teaching.

In the present situation the main tools for large number of undergraduate students still consist of writing their solutions on ordinary paper, partly by some help from calculators. One of the main outcomes of the proposed system is going to be the design and implementation of a sensible adapted communication and collaboration distance learning environment, which will greatly enhance undergraduate students possibilities for writing digital solutions of for instance their exercises or project work using standard mathematical and scientific notation in an easy and time-effective way at any time and at any place. Although the system should tolerate a range of explorative ways of working, only a limited number of digital sources adapted to the special needs of the targeted group, are going to be available in order to lower the user threshold to an absolute minimum. This includes interfaces for light-pens, electronic blackboards, digital document cameras, exchange of multimedia rich content, accessing of a limited amount of functionalities from advanced Computer Algebra Systems, online assessments, etc. Furthermore, an effective distance learning educational program at the undergraduate level, which contains a "very smooth and adapted" introduction to Computer Algebra Systems, definitely promotes and simplifies the use of the standalone Computer Algebra Systems at the graduate or higher level. Content management is an essential ingredient to the delivery of these user-oriented services in a pedagogical framework, which supports learners, teachers, and course

organizers to retrieve previous course material, structure new educational material and deliver high quality communication support (assessment, feedback, discussion, and course management) for the benefit of those pursuing *e*Learning. The work program is designed to provide state of the art management services which have been developed with the end users in mind. Thus, the focus of the work emphasizes delivery via easily available current technologies for the delivery of various mechanisms connected with student-student, student-teacher, and teacher-teacher communication.

6. Proposed design of natural science course modules

Each course is supposed to consist of several modules where the content actually are produced by using a range of different digital sources, including the possibility of using high quality videoconferencing and application sharing in distance educational courses. It is expected that each module might contain a wealth of different types of course material as lecture notes (from digital blackboards), resumes, examples, calculations, training exercises, compulsory exercises, interactive animations and simulations, video, etc. The system is designed in such a way that previous developed material is stored in a similar manner as the online production of material during the course lectures. It is expected that the natural science learning material at least is grouped together into 5 classes consisting of

- Different types of online material from the lectures
- Pre developed course material in form of learning objects
- Different types of exercises
- Different types of self tests and evaluations
- Portfolio assessment

It is also desirable to use the natural science learning modules in combination with new real time collaboration technologies and audio-video-data learning environments. This includes both asynchronous and synchronous communication services such as streaming video, use of technology transparent studios with integrated AV and shared data environments (documents, whiteboards, high quality multi point fluid video and crisp audio solutions on H264 etc.), and remotely managed virtual conferencing services over reliable networks.

Figure 4 displays the dependence of the different technologies in an interactive natural

science course module solution. Demonstrations in one course module might run mathematical calculations and make up plots and graphs through external software tools like MapleNET, while MapleTA offer students self tests and evaluations. MapleNET/TA offer low user thresholds for the end user and operate through flexible interfaces where the end user might operate either in calculator mode (enter expressions as on an advanced calculator) or in standard mathematical and scientific mode (enter mathematical expressions as in their text book). It should however be noted that the universities must have quite high competence and infrastructure in order to operate and exploit the potential of these new solutions. This includes both system administrators and teaching and instructional personnel.
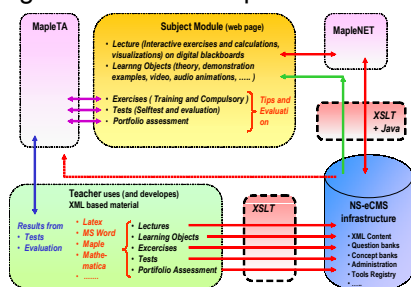

Figure 4: The NS-eCMS proposed interactive Natural Science course modules

7. Pedagogical characteristics of the services

A wealth of distance education infrastructures, including tools for content development and delivery, have been developed over the last few years aiming to overcome geographical and temporal constraints in the learning process. Such tools include content publication mechanisms, course development tools and course delivery systems including virtual classroom functionality and collaboration. However, existing commercial as well as open source tools for eLearning management focus on the delivery of course on generic topics while at the same time they lack key functionality and infrastructure for supporting time efficient communication in the eLearning process in natural sciences.

Faculty time is a limited resource and online teaching increases the workload and take time from research. Many universities and professors demand interactive facilities, not complex distance teaching services that are "killing the instructor." This community, which includes students, educators, and information managers, will benefit from services that address the needs

of obtaining time efficient distance teaching processes. Topics included are organization, publication, delivery, internal information representation through emerging open standards such as XML/MathML, course development, user-friendly and dynamic interfaces for submitting and reviewing technical multimedia rich content such as server based interactive simulations, integration of scientific calculation tools, on-line self-assessment / examinations etc. Currently, no comprehensive services that address the above issues in a user-friendly manner tailored to undergraduate- and graduate higher education students exist.

The NS-eCMS project proposes an infrastructure and services for the mass deployment of eLearning initiatives in natural sciences. While the project does not aim to change the traditional educational processes of academic institutions in those fields, it is expected to have a positive impact in the eLearning processes by facilitating close collaboration and more time-efficient communication between learners and instructors and by enabling the efficient exchange of media rich content, which currently is addressed inadequately by available tools. Rather than altering educational processes, the above two aspects of the proposed solution are expected to make on-line initiatives more effective and promote the launch of new eLearning programs where none exist due to the lack of effective and cost efficient solutions.

A comprehensive platform service does not yet exist with a number of desirable pedagogical characteristics adapted to the needs of natural sciences. Such characteristics include: (i) user-friendly interfaces for the organization, submission and retrieval of documents containing scientific and mathematical formulas (ii) dynamic presentation of such formulas through MathML (iii) flexible internal information representation through standards that ensure portability of content between commercial and open source tools (iv) effective synchronous and asynchronous collaboration tools (v) inclusion of scientific computations (vi) effective presentation of problem solutions (vii) minimum requirements for installation of client tools on behalf of the user (ideally no requirements except of the use of an Internet browser) (viii) real-time information presentation through high quality multipoint videoconferencing (ix) inclusion of virtual laboratories (x) cost and time effectiveness for the deployment to a large number of learners (xi) easy administration.

8. Implementation considerations

The system will be implemented as a 3-tier web-based application. The back end (or server side) of the architecture will be a commercial relational database (Oracle 8i) that will serve as metadata and statistics storage. Metadata information will be published on the web through a commercial Application Server (Oracle Application Server 9i). The middle tier will be developed as servlets and JAVA classes. The front end (or client side) will be developed as JSP applications.

The use of JAVA ensures that the infrastructure is portable to any operating system. The web access ensures that the requirements from the user for accessing the system will be minimal, and specifically a simple web browser with MathML plug-ins.

Figure 5 displays the 3-tier implementation. As shown in the figure, independent services will be developed for each of the 4 identified user groups: *Public Services* aimed at learners, *Provider Services* aimed at content providers, *Management Services* aimed at course managers, and *Administrator Services* aimed at repository administrators.
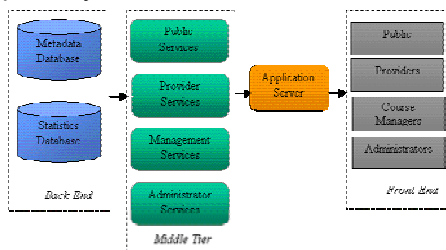

Figure 5: The 3-tier implementation

Performance and scalability are of key importance for the adoption of the system in a wide range of applications. The NS-eCMS architecture ensures that the system is scalable in terms of the amount of information managed and that performance does not deteriorate as the managed information grows in volume. Scalability and performance are ensured through distribution of metadata and content, and multi-threading of connections.

The NS-eCMS system supports a network of independent information management nodes ensuring the installations can grow while maintaining autonomy for participating parties. For example, large institutions may opt for a number of NS-eCMS nodes, each managing the needs of particular departments. The nodes communicate with distributed search protocols to ensure that the underlying complexity is transparent to the users, who access information uniformly from a single point on the web. Users do not need to know

where the information they access is managed.

Database connections are established through shared servers. While shared servers connect to the database, users connect to the shared servers. This indirect database connectivity ensures that the system resources are preserved and well managed as the number of users connecting to NS-eCMS increases. Given the fact that NS-eCMS is a web-based application that could potentially be accessed by hundreds or possibly thousands of users, system resource management is critical for scaling and performance purposes. Multi-threading ensures that resources are well managed even under stress. The shared servers automatically perform connection load balancing.
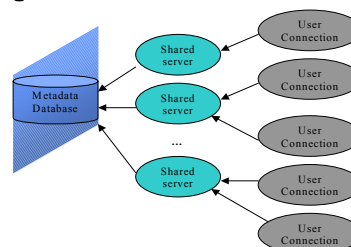

Figure 6: Multi-threaded connections

Applications that make use of databases often need to frequently obtain connections to the database. For example, a popular website that is serving out information from back-end database may need to obtain a database connection for each client who is requesting a page with their browser. To ensure that application is capable of responding to each client fast enough the time spent performing each of it's task is profiled. One of the most time expensive tasks involving accessing databases is the initial creation of the connection. Once the connection has been made the transaction often takes place very quickly. This is where the connection pool comes in, by retaining a pool of already opened connections so the application can simply grab one when it needs to, use it and then hand it back, without the long wait for the initial creation of the connection.

9. Target groups

The project focuses on the academic community in the areas of distance teaching of natural sciences. This community has varying needs due to the pedagogical methods used in different circumstances. For example, use of highly specialized notation is essential for the transfer of knowledge at undergraduate- and graduate level in higher education. Specifically,

the following target user groups in those academic areas are identified:

- Higher education undergraduate students
- In-service training of engineering professionals
- Undergraduate academic institutions
- Educational content providers
- Tutors of natural sciences
- Educational repository administrators

Engineering and science institutions throughout Europe would benefit from the proposed services for the support of eLearning by deploying the platform to enhance existing programs and launch new ones. Professionals and higher education students will benefit from the single point of access to a wealth of content and the easy interaction services. Given the size of the academic community in engineering and natural sciences, the project results will have a large dissemination audience. Furthermore, given the challenges in eLearning of such subjects, the potential impact of the proposed easy access and low cost infrastructure is large and European wide.

10. Conclusions and future work

This paper presented the NS-eCMS educational content management, collaboration and communication system for the support of distance teaching and learning of natural sciences. The proposed system will benefit undergraduate learners and undergraduate academic institutions involved in natural science teaching/instruction by providing services that addresses the entire educational process, from information exchange to information management, computation execution and examinations. The purpose of the system is to provide more time efficient communication services and an open scalable platform for the homogenous publication, management, and dissemination of possibly distributed, heterogeneous educational material developed by educational content providers across Europe while maintaining the autonomy of participating organizations. In addition to providing services for the publication and management of educational content, the system provides services for all user groups participating in the asynchronous eLearning process, namely learners, content providers, course managers, and repository administrators.

The presented architecture are currently implemented in the context of MINERVA-SOCRATES action project 110159-CP-1-2003-1-NO-MINERVA-M *"Content Management and collaboration System for eLearning of Natural Sciences"* (NS-eCMS 2003)*.*

Forthcoming work will focus on how the developed services could be extended to support distance teaching in more general engineering disciplines like for instance electrical and mechanical engineering. It is expected that these subjects will give additional challenges for the development of dynamic and interactive web-presentations containing large amounts of media rich educational content, which could be distributed synchronously in real time on broadband networks through integrated AV and data environments.

References

Apache Cocon (2003): The Apache CoCon Project, [on-line], http://cocoon.apache.org/

Blackboard (2003): [on-line], http://www.blackboard.com

eCMS (2001): "Content Management Middleware for the support of eLearning across Europe", MINERVA-SOCRATES funded project 90613-CP-1-2001-1-GR-MINERVA-M, [on-line], http://elearning.noc.uth.gr

e-Learning (2001): [on-line] ftp://ftp.cordis.lu/pub/documents_r5/natdir0000001/s_1530009_20010125_143306_GPRC001349en.pdfHarris D., DiPaolo A., Goodman J. (1994): ADEPT proposal, [on line], http://stanford-online.stanford.edu/history/fulldesc.html

ETB: European Treasury Browser:[on-line] http://www.eun.eun.org

Haugen H., Ask B. and Hjeltnes T. (2002): "Model for an European, Networked University", http://www.hsh.no/ln/inf/menu

Learning Technology Standards Committee (2000): Approved Working Draft of the IEEE Learning Technology Standards Committee (LTSC) Learning Object Metadata Working Group. IEEE P1484.12 http://ltsc.ieee.org/doc/wg1/ltsa/ltsa_05.pdfMaple (2003): [on-line], http://www.maplesoft.com

MapleNET (2003): [on-line], look at the (hidden) interactive demo site http://maplenet.maplesoft.com

Nikolau C., Georgakopoulos G., Tsalapatas H. (2000): "A Federated Digital Library for Universities' Grey-Literature: Practical Issues and a "Transient" Analysis". University of Crete Technical Report

NS-eCMS (2003): "*Content Management and collaboration System for eLearning of Natural Sciences*", MINERVA-SOCRATES founded project 110159-CP-1-2003-1-NO-MINERVA-M, http://ns-ecms.noc.uth.gr/index.html

sebra (2003): Centre for broadband applications, [on-line], http://www.hist.no/aft/sebra/english/index.php

Stav J. B. and Tsalapatas H (2004): "*A Content and Learning Management Infrastructure for Distance Education of Natural Sciences*", proce. of The 2nd European Conference on eLearning, Glasgow, 2003. J.B. Stav and H. Tsalapatas: "*Open Learning Management Services for Distrubuted Teaching in Natural Sciences*", proce. from the Second International Conference on Multimedia and ICTs in Education, Badajoz, 2003. J. B. Stav, H. Tsalapatas, T. M. Thorseth, C. Kalantzis, "*System Design of Scientific Elearning Management Services*", to be published in the proceedings of the Ed-Media Conference, Lugano, 2004.

The Dublin Core: [on-line] http://purl.org/metadata/dublin-core

Tsalapata H., Stav J. B. , Brna P., Kalantzis C., (2003): "*eCMS: eLearning Content Management Middelware*", published in the proceedings of the 2nd *Euopean Conference on e-Learning*, Glascow, November 2003. H. Tsalapatas, J. B. Stav, P. Brna, C. Kalantiz and S. Tsalapatas: *Towards a Federated Digital Library of European Educational Content*, published in the proceedings of the Second International Conference on Multimedia and ICTs in Education, Badajoz, 2003. Hariklia Tsalapatas, John. B. Stav, Christos Kalantiz, "*Content Management middleware for the Support of Distributed Teaching*", Electronic Journal of eLearning (EJEL), http://www.ejel.org, June 2004.

Tsalapata H., Brna P., Stav J. (2002): "eCMS System Design Report", [online], University of Thessaly Technical Report, http://elearning.noc.uth.gr/docs/DRV01.doc

Tsalapata H., Kalantzis C., Brna P., Stav J. B. (2003): "eCMS System Implementation Report", [online], University of Thessaly Technical Report, http://elearning.noc.uth.gr/docs/IRV01.docWebCT (2003): [on-line], http://www.webct.com

Wolfram (2003), [On-line], http://www.wolfram.com/

Xmath (2001): [on-line] http://www.xmath.org