Building a European database of mathematical e-learning modules

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Abstract— The EU project dMath will build a European database of mathematical e-learning modules. The modules will be organized according to standard textbook levels and a module is divided into independent objects for downloading by a publisher to create an online course in mathematics. This database may be used as an online dictionary as well and is evolutionary in the sense that developers may create own objects for the database (reviewing by the editorial board of the database).

Existing solutions on a professional level in web-based e-learning in mathematics have important drawbacks. The provider of the course often does not have any control with design and content. This will make it difficult to make changes and adapting to local conditions. The lecturer then has to adjust his curriculum to the e-learning system and not vice versa. The database will give the publisher the opportunity to download from a wide range of reusable learning objects (RLO) and perfectly adapt the course to her needs. The system also offers a sophisticated online calculator which is unique of its kind focusing on pedagogical value.

Index Terms— Mathematical e-learning, Online Calculations, Java Server Pages, Pedagogical Value, Interdisciplinary Mathematics, Markup Languages, XML/MathML Database Client, Content Management Systems (CMS), Reusable Learning Objects (RLO), Shareable Content Objects Reference Model (SCORM), Learning Management System (LMS), Evolutionary User Controlled Development (EUCD).

1. *Introduction*

The project dMath [1] [2] in the EU Leonardo da Vinci Programme [3] is a follow up from the EU Minerva project Xmath [4]. The intention is to commercialize Xmath by using the framework and the technologies of the Xmath project, mainly connected to the web technologies XML/MathML [5] and Mathematica/webMathematica [6]. dMath will build a European database of mathematical e-learning modules using this innovative technology. A publishing system with the working title SciLAS (Scientific Learning Authoring Suite) is being developed including a XML/MathML editor as a fat client to the database repository. The repository itself will have the working title dMathArchive. The repository objects, called Reusable Learning Objects (RLO) and being a part of a module, may have a link to the Xmath Calculator [7] for online step-by-step calculations and are free to download for the publisher. The publisher may then combine different objects to create an online mathematical course without having skills in advanced web technologies.

The main idea is to get a high degree of independence compared to a ready-to-use course developed by someone else where the provider of the course may not interfere either with content nor layout. This will provide support for cooperative development (evolutionary system), reuse (RLO), exchange of courseware and creating a possibility to adapt courseware to the requirements of different authors, educators and students.

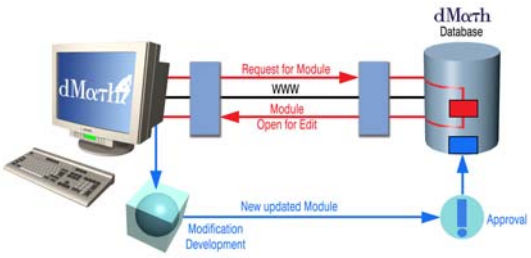

Figure 1: The dMath Database System

The partners of the dMath project are Buskerud University College (promoter) [8], Czech Technical University [9], Soft4Science [10], Pontificial University Comillas of Madrid [11], Savonia Polytechnics [12], Sogn og Fjordane University College [13], Industrial Documentation [14] and Slovak Technical University [15].

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2. THE DIFFERENT PARTS OF THE SYSTEM

The dMath system consists of three main parts.

A. The software framework Scientific e-learning Authoring Suite (SciLAS)

1. XML/MathML Authoring tool SciWriter with a palette of mathematical symbols, a fat client to the system [16]
2. Learning content management system (LCMS), CMS for learning content [17]
3. SOAP, Simple Object Access Protocol, published by W3C [18] (authors/editors)
4. SCORM package, Shareable Content Object Reference Model, a set of specifications published by ADL, Advanced Distributed Learning [19] (publishers, local LMS).

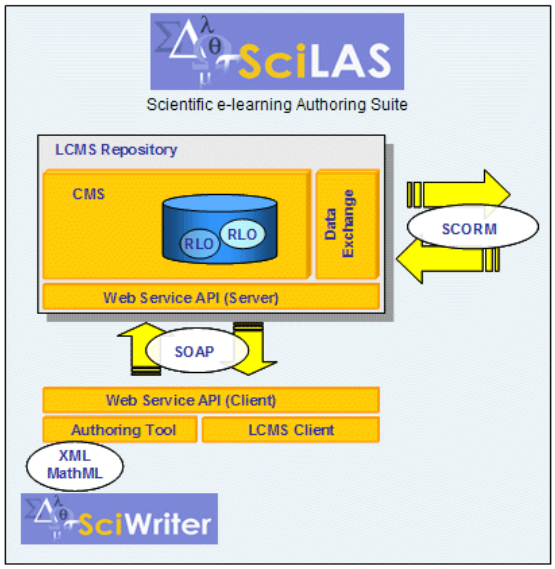

Figure 2 Architecture of the software framework

B. dMathArchive (repository of RLO's)

Modules are divided into the type object (RLO) which may be downloaded by a publisher. Characteristics of RLO's will be

1. **Modularity**, RLOs are self-contained , each object can be taken independently
2. **Reusability,** a single RLO may be used in multiple contexts for multiple purposes
3. **Interoperability**, RLOs should be independent of both the delivery media and knowledge management systems
4. **Accessibility,** a RLO should be tagged with metadata so that it can be stored and referenced in a database
5. **Granular structure,** RLOs can be combined to form a hierarchy such as Module, Course or Curiculum. The lowest level of granularity is called an asset, some media like sound, animations and JPEGs cannot define a RLO alone (cannot be tracked by a local LMS using SCORM runtime environment)

C. Xmath Calculator

Step-by-step online calculator for training and simulation. Available as an independent resource on the web [7]

SciWriter [16] is an editor for authoring scientific articles and mathematical or technical e-learning content. It is a single source multiple publishing channels system (LaTEX, XML/MathML, HTML, SCORM package, e-mail). MathML is important in the project rendering mathematics like text and not graphics. For Microsoft explorer you then will need a plug-in (free download). An option is to use HTML and publish equations as images on the web.

By using the XSLT stylesheet for MathML (universal MathML stylesheet) provided by the W3C Math Working Group [5], SciWriter documents containing MathML nodes can be viewed by the following web browsers:

1. Microsoft explorer using plug in MathPlayer [20]
2. Microsoft explorer using plug in TechExplorer [21]
3. Mozilla [22]
4. Netscape [23]

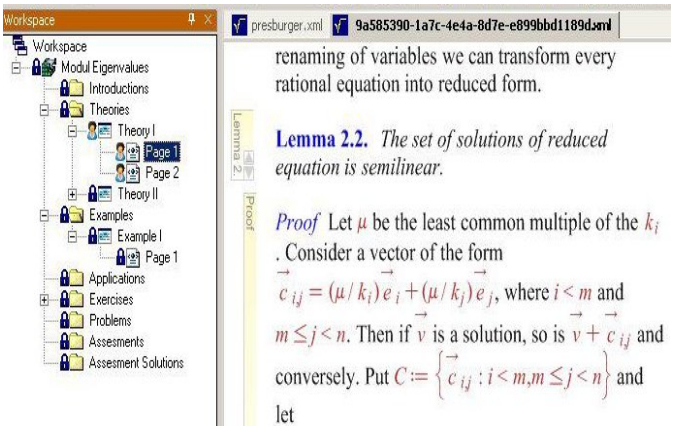

Figure 3 SciWriter, Module Eigenvalues in client workspace

The RLO's of the archive are then developed by an author/editor using the SciWriter client (SOAP). A publisher may download RLO's from the repository (SCORM) to a local learning management system (LMS) and then being quite independent in how to set up a web.-based course in mathematics and without being an expert into web technologies. The publisher may be the provider of the course for students and engineers in industrial companies needing further

education in mathematics.

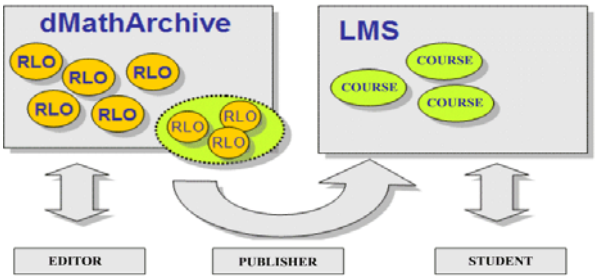

Figure 4 Using the Archive

The Xmath calculator is further developed. A sophisticated online calculator has been missing in connection with mathematical and scientific e-learning and will increase the performance/price rate of the system.

3. *Modules and objects*

A module is a collection of objects- a menu card of objects- which are grouped under a mathematical topic. Metadata assigned to the object may suggest to the publisher the order in which these objects can be organized. As an example the main topic level could be Calculus, next level Functions and then the module Continuity divided into different objects for download.

A module may contain an introduction object, theory objects, examples objects, exercises objects, assessments objects, applications objects, graphics objects, animations objects and student projects objects. Not all modules will necessary include all the different kinds of objects. The objects in a module may be downloaded independently of each other but the publisher will have access to information about the connection between the objects and how to organize them. However if a publisher only needs the animation object, say, he will then download only this object.

In the project modules in Number Theory, Calculus, Geometry, Differential Equations, Linear Algebra, Statistics and Probability, Numerical Methods, Interdisciplinary Mathematics and Fourier Series will be developed.

4. Interdisciplinary Mathematics

Some of the modules require a special attention. The project is highly Multidisciplinary and Interdisciplinary and will develop modules in interdisciplinary mathematics [24]. Our aim is not to define what interdisciplinary mathematics is (similarly as for cybernetics). Our modules called "Discovering Mathematics" do not belong to any specific field of mathematics; they are built primarily from the "Problems point View". Mathematical problems, mostly drawn from calculus, are presented in a form which enables to create, in the process of their solution, an interconnected network of new problems.

To help the user to develop ability in solving problems the network then helps to find easier problems which she can solve if she is not able find a solution of the first problem or more complicated ones of the same character.

5. *Mathematical dictionary*

The interface to the repository of modules (dMathArchive) is intended to be easy to use and a selected mathematical item may be search for to find the definition and an introduction to the item. This will work like a mathematical dictionary with a wide range of items being present. Searching for "Eigenvalue" the definition and an introduction to the topic "Eigenvalue" will show up.

6. *Evolutionary system*

In the design of the dMathArchive the concept of "Evolutionary user controlled development" (EUCD) will be important. The dMath project will implement this concept by letting users/publishers develop their own objects for upload to the database repository or modify existing modules/objects. This will do the archive "continuously growing" and give it an "agile development " with focus on changes. Of course the modules and objects have to be reviewed by the editorial board of the archive.

The same philosophy may be used for developing software packages for the Xmath Calculator.

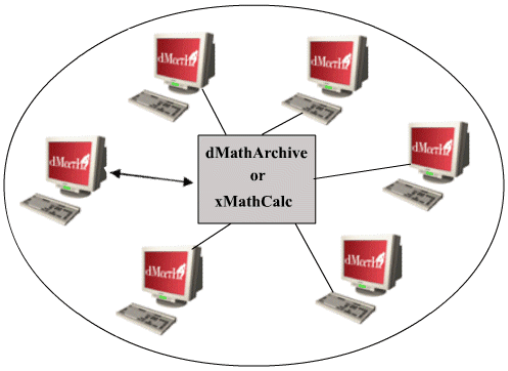

Figure 5 Evolutionary User Controlled Development

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7. XMATH CALCULATOR

The Xmath Calculator is an online tool for mathematical simulation and training with focus on pedagogical value. The calculator gives intermediate steps for arbitrary input from the user in a wide range of applications.

An expression is broken down and analyzed by the developed software packages. The rules familiar to hand calculation are given and so are the intermediate results. By scrolling the user may view the first step, second step and so on. The user may then choose to go further by hand after the first or second step. In the same way an expression may be broken down into different levels so are the calculating steps broken down accordingly. This gives a structured output as would a professor do it on the blackboard stating the rules on each level.

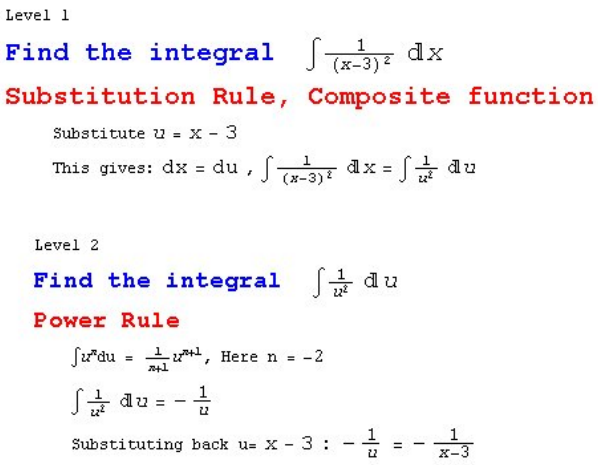

Figure 6 First two steps of integration task

The calculator is based on webMathematica technology [5]. The output may be chosen as MathMLForm giving a non-image format to be rendered in Microsoft Explorer by using proper stylesheets and a free plug-in. The input files are XML enhanced by special tags saved as *.jsp (Java Server Pages) calling the Mathematica software packages by using Mathematica commands.

webMathematica is based on two standard Java technologies: Java Servlets and JavaServerPages (jsp). Servlets are special Java programs that run in a Java-enabled web server typically called a “Servlet Container”. Both the markup languages MathML and SVG (vector graphics) may be used in a *.jsp file.

```
<math xmlns="http://www.w3.org/1998/Math/MathML">
 <mrow>
  <mi>d</mi>
  <mi>x</mi>
  <mo stretchy='false'>]</mo>
  <mo>=</mo>
 </mrow>
 <mrow>
  <mfrac>
   <mi>d</mi>
   <mrow>
    <mi>d</mi>
    <mi>x</mi>
   </mrow>
  </mfrac>
  <mo stretchy='false'>[</mo>
 </mrow>
</math>

<msp:evaluate>
If[ test===1,  MSPFormat[result1, MathMLForm],
                    MSPFormat[ Integrate[function,x], MathMLForm] ]
</msp:evaluate>
```

Figure 7 MathML and webMathematica tags in *.jsp files

8. FURTHER DEVELOPMENTS

The dMath database is now being uploaded with the modules and will be ready for use in September 2006. The RLO’s will then be tagged with semantic metadata in different languages the database then being searchable in a multilingual environment. This kind of enrichment is important to make the system easy to use in European countries.

The testing period on the full system is important. A transnational network will be established developing an innovative e-learning pedagogy in mathematics [25,26] and improving the access and willingness of teachers and trainers to use mathematical e-Tools. It will be important to improve mathematical teaching and strengthen the recruit to mathematical education.

The network will arrange seminars and conferences for European trainers, teachers and others being interested in using the dMath products: the XML/MathML word-processor, uploading to the “Orange” content management system, downloading to a local LMS using the SCORM package [19] and then tailoring a course without being an expert into advanced web technologies, and using the Xmath Calculator

9. CONCLUSION

The dMath project will build a database of Reusable Learning Objects (RLO) focusing on cooperative development, reuse, exchange of courseware and the possibility to adapt to local conditions. This will enable the teacher to build up his own professional designed course without having skills in advanced web technologies. This gives a high rate of performance/price because one do not pay for the download, there will not be too much of course design working and the

teacher may adapt the course perfectly to her needs.

The dMath project focuses on pedagogical value. This is important because one of the most frequently asked questions connected to e-learning is about its pedagogical value compared to traditional methods. The teachers are somewhat afraid of the necessary changes in their behaviour using e-learning resources in the ordinary classroom and not for saying in the virtual classroom. The role of the teacher may be more like an adviser than a lecturer.

Using e-learning resources will develop a new kind of pedagogic using innovative methods. The establishment of thematic networks aiming at collecting, analysing and disseminating innovative learning, best practices and new learning tools is then necessary. Also the exchange and dissemination of innovative methods that improve access, readiness and willingness of teachers and trainers in general to engage in further training is important.

ACKNOWLEDGMENT

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