AUTOMATED LEARNING TOOLS

A memo for the preparation of an FP6 proposal

1. Introduction

European Union has adopted a framework programm, called the *Sixth Framework Program FP6*, for the period 2002-2006. We seek funding from the thematic area *Information Society Technologies* of this program for an *integrated project* under the topic of

AUTOMATED LEARNING TOOLS.

This is a large European project for the creation of an eLearning standard in mathematical sciences, as well as materials and methods for extensive use of it in eLearning. This project will lead Europe to a future in which best experts of mathematics education can collectively produce online learning material for the general use of all educational institutions.

This memo is intended for potential partners of the consortium and it describes the topic and project plan.

2. The *AUTOMATED LEARNING TOOLS* Idea

2.1. Background

There is a clear need to develop electronic learning of mathematical sciences in Europe. Many countries face a serious shortage of teachers in technical subjects. At the same time demand for people with basic scientific training increases.

It is not possible to create knowledge based Europe without a solid educational infrastructure. Numerous educational institutions have to meet a growing demand for teaching with diminishing resources.

Electronic learning is a cost effective solution to deliver education in many areas. At the same time it offers possibilities which go beyond traditional teaching methods. Recent advances in software technology have made it possible to develop a new generation of eLearning tools, especially in mathematics and sciences close to it.

Mathematics is a particularly suitable area for electronic learning. With present day information technology it is possible to create interactive learning tools which themselves know an impressive amount of mathematics. This is to a large extent due to the exact and a priori nature of mathematical knowledge. Many areas of exact sciences rely heavily on basic mathematical knowledge. On the other hand, there are also areas of e.g. medical studies that have the same nature.

There is clear evidence that European educational system has not been able to maintain the level of mathematical skills of students leaving school. Whatever the reason, the fact remains that basic mathematical knowledge is one of the cornerstones of information society, and educators face the challenge of training more people with fewer resources. One approach to solving this puzzle is *automated learning*. Taking full advantage of information technology in education, this can provide a more effective delivery method of education resulting to a greater availability of education within the Union.

By means of horizontal integration, the proposed eLearning project will reach the critical mass necessary for a breakthrough in harnessing the full power of advances in IST for the use of educators throughout the community.

By making a more equal access to education possible, the multilingual online learning project *AUTOMATED LEARNING TOOLS* allows European citizens, in all Union regions, the possibility of benefiting from latest advances in knowledge-based society. Concentration on the next generation of eLearning will bring IST applications and services within reach of everyone involved with education

2.2. Electronic Learning of Mathematics

The typesetting language TeX made it possible for scientists to send each other scientific papers via electronic mail. However, TeX documents contain only typesetting information. Scientific formulae encoded using TeX do not offer means of understanding the meaning of the formula automatically. This means that the possibilities that the computational power of computers have in actually solving mathematical problems is not invoked by TeX.

The recent emergence of MathML[i] and OpenMath[ii] is, therefore, a great step forward in electronic communication of mathematics via the internet. These protocols make it possible for internet pages to communicate automatically with mathematical software. This opens completely new vistas for mathematics education and research.

It can be expected that groups of educators of science all over the world will become engaged in generating web-based course material for online learning. To some extent this has already happened but usually the scale of the projects has been restricted.

These groups could benefit enormously from co-operating with each other, especially in mathematics. Mathematics is relatively neutral and universal and provides an excellent field for educational co-operation. Cultural differences are minor. The main difference between groups is language.

2.3. The AUTOMATED LEARNING TOOLS concept

Numerous *AUTOMATED LEARNING TOOLS* systems exist already today. The goal of the current *AUTOMATED LEARNING TOOLS* project is to organize a consortium which collects together best European expertise in electronic learning to create a multinational and multilingual knowledge base of educational mathematical content.

For this end a *CONTENT DICTIONARY* standard will be developed. This standard is analogous to the OpenMath standard developed for the communication of mathematical content in the internet, and its importance is of the same if not even bigger magnitude. What is needed now is the next step: find a way to standardize communication between educational resources. The basic educational content of mathematical topics needs to be analyzed and the right way to express that content has to be developed.

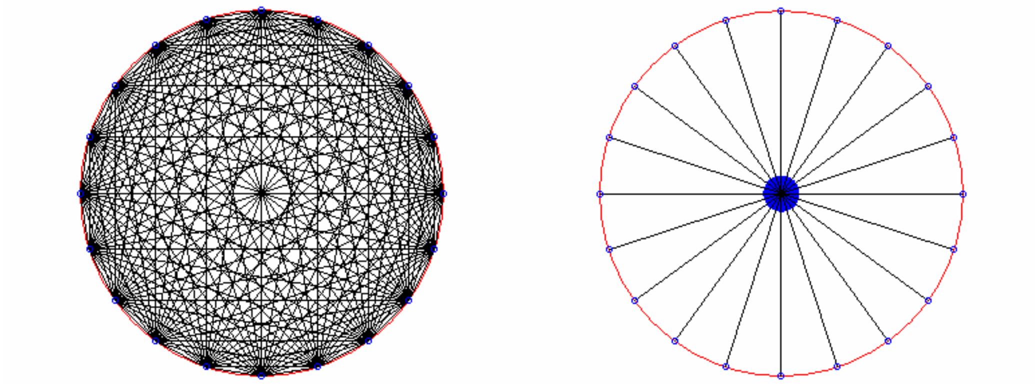

Diagram 1: The effect of content dictionaries

The dots on the boundary of the circle illustrate 20 professors writing educational materials and trying to share that with their colleagues. If there is no common agreement about the classification of the content one needs to build 190 bridges between the materials produced by individual authors so that complete sharing would be possible. The diagram on the left shows these 190 bridges. The circle on the right corresponds to the situation where all use the same content classification. Then only 20 bridges allow complete sharing of the material. In any large university there are basic mathematics courses involving 20 or more instructors at one time. So the complications of this diagram may represent the situation in one department only and in one course only.

Diagram 1 pictures two situations: one in which educational material is produced and shared without a standard, and one in which a common standard is used.

The *CONTENT DICTIONARY* technology makes it possible to address the problem of partially correct student response.

The advantages of a standardized language for representing content are obvious:

- Educators can share resources, for example mathematical problems.
- Students can take advantage of resources elsewhere.
- Distance learning.
- Publishers can provide books that take advantage of public resources.

It is a natural idea to start the creation of such a knowledge base from mathematics, thanks to its abstractness and exactness, especially as major milestones have been recently achieved in the area of electronically communication of mathematical content. On the other hand, the *AUTOMATED LEARNING TOOLS* idea tools can be applied in the future to any area, e.g. to medical studies.

A major feature of the ALT system will be its ability to evaluate partial knowledge or partial correctness of the student response. The student may master a part of the problem or an easier case but not the whole problem. It is essential that an automated learning system, when used for evaluations or self-assessments, can give "partial credit" to students.

In addition to the structure provided by the *CONTENT DICTIONARY* technology, an essential feature of the knowledge base will be multilinguality and multiculturality. This means that educators everywhere in Europe can immediately take advantage of the online materials produced within this system.

The very idea of *AUTOMATED LEARNING TOOLS* is to put the user on the driver's seat in eLeraning. The *AUTOMATED LEARNING TOOLS* idea involves that, for example, one and the same mathematical problem may look very different depending on where in the world it is presented to the students. Appreciating such cultural differences is a part of a successful teaching process. A properly designed automated learning environment will be able to share educational knowledge across cultural boundaries.

2.4. The CONTENT DICTIONARY Concept

A high-level international consortium should take up the task of establishing a *CONTENT DICTIONARY* standard for communication of educational content electronically. Steps in this direction have been already taken by TopicMaps.Org[1] and the Open University of the Netherlands with its Educational Modelling Language.[2]

The standard would by no means be restricted to mathematics but can be applied to any field where the educational material is sufficiently exact so that the content can be standardized for electronic communication. For example, medical education has such aspects.

Using the standard one can specify the educational content of an individual course, part of a course or just an individual test question. The task of establishing such a specification is quite challenging, comparable to writing a comprehensive textbook on the field. Therefore it is instrumental that the work is done collectively and that the results are widely applicable.

Once the *CONTENT DICTIONARIES* are ready, publishers of textbooks can produce software that owners of their books can download and thereby establish a connection between the online material and their book. Students solving the same mathematical problem in different parts of the world, but using a different textbook, would still get automatic electronic instruction to review material on a particular page of their respective books.

The following steps can be isolated in the process of developing *CONTENT DICTIONARIES*:

- Developing the underlying *CONTENT DICTIONARY* language.
- Developing *CONTENT DICTIONARIES* for central areas of mathematics.
- Using the *CONTENT DICTIONARIES* to produce actual educational material such as problem databases.

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[1] http://www.topicmaps.org/
[2] http://eml.ou.nl/

- Establishing links between the *CONTENT DICTIONARIES* and material produced by publishers.

3. An example: The Helsinki Learning System[iii]

The **Helsinki Learning System (HLS)** project of one of the consortium partners, the University of Helsinki, has developed a test *CONTENT DICTIONARY* language, as well as experimental tools for maintaining *CONTENT DICTIONARIES* and for generating test questions that are structured according to these *CONTENT DICTIONARIES*.

4. Integrated Project: ALT

The integrated project ALT is an instrument to support objective-driven eLearning research, where the primary deliverable is new knowledge. By mobilizing a critical mass of the best resources, the integrated project ALT is expected to have a strong structuring effect on the fabric of European eLearning research.

Integration in this project takes various forms:

- *Vertical integration:* encompassing the "value-chain" from knowledge production in institutions of learning of different level from highschool to universities, and technology development in sofware companies, to their transfer to educators and students alike.
- *Horizontal integration:* there is a strong multidisciplinary nature in this project, with regard to its scientific and technological components.
- *Activities integration:* the project integrates various research activities with each other and with sofware development, take-up activities, protection and dissemination of knowledge and training.

Inter-sectoral integration: the project involves a partnership between public sector research organizations, mainly academia, and SMEs.

Financial integration: the project will be carried out on the basis of overall financing plan involving a significant mobilization of public and private sector funding schemes

Project Plan

The FP6 funded *AUTOMATED LEARNING TOOLS* concortium will consist of about ten teams with about 100 members altogether. The concortium will consist of

- A **production unit** of SME's with high expertise in production of online learning tools.
- A **research unit** of three teams of experts in the area of research of eLearning.
- A **development unit** of three teams of professors developing content.
- A **dissemination and user support unit** of two or three universities engaged in virtual education.
- A **management unit** of one team.

The *production unit* will produce the actual software tools needed to fulfill the overall goals of the project. It will

- Produce software for creating, maintaining and editing the system and educational material based on it.
- Develop distributed database technology for the software.
- Produce user interfaces for using the produced material.

The *research unit* will carry out the creation of *CONTENT DICTIONARY* language and the various *CONTENT DICTIONARIES*. It will produce *CONTENT DICTIONARIES* for major mathematical courses.

The *development unit* will produce the content on the basis of the *CONTENT DICTIONARIES* produced by the research unit. It will produce a large multilingual database of mathematics problems.

The *dissemination and user support unit* will educate users and test the products. It will

- Organize testing of the material.
- Educate interested parties in using the material.
- Disseminate information about the product.
- Activate potential users all around the world to produce course material based on these *CONTENT DICTIONARIES*.
- Provide support for the users of the system.

The *management unit* will

- Co-ordinate the project.
- Manage the finances of the project.
- Negotiate with commercial companies about production of supporting software.
- Negotiate with publishers about production of links between their books and the generated CCD's.

5. Self-sustained continuation

Diagram 1 above gives a good idea of the complexity of educational materials and methods. On one hand there are textbooks, in fact, a very large number of them treating any given basic course. On the other hand there are various on-line solutions that professors have developed. Standardization will make it possible to use all of these effectively together. Provided that good examples, high quality implementations and prompt user support are provided, the academic world will produce high quality content confirming to this standard. This will make it possible for publishers to enhance their books with the databases of problems which are already being developed at universities and other educational institutions. This enhancement of books will happen through mapping a given Content Dictionary to the table of contents of the book in question. This commercial activity will generate revenues that will finance continuous user support of the automated learning tools to be developed by this proposal.

6. Budget

Duration	3 years
Number of teams	10 (excluding management team)
Average EU funding per team per year	150
Average other funding per team per year	150
Management per year	150
Total per year	3 150
Total per 3 years	9 450 K€

[i] www.w3.org/TR/MathML2/
[ii] www.openmath.org/
[iii] mark.math.helsinki.fi/HLS/