EFFECTIVE INTEGRATION OF COMPUTING TECHNOLOGY IN MATHEMATICS AT U.S.T.L.

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ABSTRACT

0.1 Abstract

During the last four years, i have been engaged in the production of multimedia units for the French national program *On line University* which wants to cover the two first academic years in sciences.

This paper presents the creation of multimedia software in mathematics, its use for teaching and that of an e-learning platform with students. This experience was both enriching and difficult. In the mathematics department, each year, a new progress has been done in integration of technologies. An analysis of the sucesses and of the difficulties will be done. In conclusion, i shall prospect the chances offered by the links between mathematics and computer science in the field of the e-learning.

1 *On line University*

1.1 The renewal of the first academic years

The development of universal education and the increasing duration of studies have led a large number of students to university and have increased their diversity, in terms of social background and of previous training. Most academic teachers are not prepared to cope with the problems caused by this diversity. Universities were urged to modify their teaching in order to reduce the failure rate. This was done by the setting up of tutorial sessions, whereby initiatives were taken by motivated local teams to develop modern teaching methods and that led to interesting successful results, especially in allowing large numbers of students to see the experimental working using visual support.

An academic science network of self-learning centers, the R.U.C.A. was set up in 1987, with eleven universities : Aix-Marseille1, Bordeaux 1, Grenoble 1, Lille 1, Nancy 1, Nice, Paris 6, Paris 7, Paris 11, Toulouse 3, Tours, (and now ten more universities). The R.U.C.A. centers were first concerned with continuous training and used custom made educational material. In 1994, they decided to create their own resources, and the students were to use these resources in their initial training. During the 1990's, the R.U.C.A. teams gained experience by systematical gathering of educational resources and developing training material for the centers. In 1995, the R.U.C.A. launched the P.C.S.M project, *premier cycle sur mesure* meaning "tailor made classes" in order to cover the first two scientific academic years.

1.2 What is *On Line University* ?

In 1998, a general model for the R.U.C.A.'s productions was adopted by the network and the P.C.S.M took the name of *On-Line University*. This project is financially supported by the Ministry of Research and Education [1].

1.2.1 The contract conditions

The *On-Line University* is a collaboration work and a collective property [2] of its creators. The site national of *On Line University* is on the Internet and, since october 2001, the access to the products are free of charge without limitation of time for consultation [3]. Maintenance and a regular updating of resources are provided [4] All public establishments in France have the possibility of downloading the products freely, without charge. Public establishments who sell formation will pay a licence. Outside, private or foreign establisments will contract with the CERIMES [5] and have to pay a commercial licence.

[1] http://www.education.gouv.fr

[2] In France, the intellectual right of property of the authors is inalienable

[3] http://www.uel-pcsm.education.fr

[4] by the U.S.T.L. and soon, by the CINES

[5] www.cerimes.education.fr

1.2.2 The Specifications

Products must be platform compatible. The choice of standards was decided, with the use of multi-platform languages (*HTML*, *javascript*, *Java*). These constraints are strong because total browser compatibility of languages does not exist. Anyhow, the R.U.C.A. keeps track of technological progress and further evolutions are already in preparation (XML ...). The staff of *On line University* program decided that it cannot require plug-ing, nor software package on the client computer. These decisions aimed to have a self sufficient program transferable to foreign countries. So formal computation [6] cannot be used for the *On Line University* program. The paradox is that many mathematicians working to produce units use formal computation during their academic work. The main tool in mathematics to introduce experimentation is not allowed and this indicates a strong limitation of this program in mathematics.

1.2.3 The Structure

Pedagogical structure has to be made flexible. The *On-Line University* program is conceived as a juxtaposition of modules. Each unit can be altered and modules can be reorganized by teachers for their own pedagogical needs inside their university. The graphical framework reflects a classical teaching structure, with two entries :
Activities : learning, practicing, simulating, observing, evaluating.
Themes : with the set of activities available on a given theme.
This teaching structure shows that, mainly, the producers of resources are scientific academic who work to integrate technologies but ignore [7] the researches in educational sciences and cognitive psychology. The ideas of distributed cognition, collaborative work are important, and i shall illustrate them in this paper.

1.2.4 *On Line University* in 2002

Already on line, there is now 885 hours of teaching ressources, in 21 units of 45 h :
— mathematics : 7 units of 45 or 30 hours = 255 hours
— physics : 7 units of 45 hours, 315 hours
— chemistry : 5 units of 45 hours, 225 hours
— biology : 2 units of 45 hours, 90 hours.
Units planned in 2002 represent 120 hours, (mathematics, 30), (chemistry, 45) , (biology, 45). *On Line University* will gather at the end of 2002, 1005 hours of ressources : mathematics, 285 ; physics, 315 ; chemistry, 270 ; biology, 135.

1.2.5 A national, cooperative realization

On Line University is an innovative creation based upon a network of teams of creators. How is it possible ? A unified piloting committee created in 1997 organizes yearly work distribution inside the network. The realization is done by multidisciplinary teams : academic teachers as far as didactic content is concerned, engineers providing technical realization. There is a link with software industries with appeals to companies, for the model, for audits and for specific computer problems. The validation of the contents

[6] Mathematica, Maple, Matlab, Scilab, WIMs ...
[7] with few exceptions

is done inside of the R.U.C.A. the resources have already been assessed by twenty five academic institutions.

1.3 The Problems in the R.U.C.A. network

1.3.1 Structural Problems

The cooperation inside such a large network is not gained at first. It are always to reinvent and to be created by discussion and commun positions emerge sometimes after long and fierce debates. The debates about the statuts are necessary but time consuming for the producers. The discussion upon the contracts between the different universities implies not only the producers of ressources but also the staff of the universities and the interests of all the participants are not always convergent. This is a huge probleme for all the producers of e-learning ressources in the world.

1.3.2 Integration of Multimedia Resources

For the students, these multimedia resources mean working at their own pace, possibilities of visualization and simulation in science for the discovery of concepts and the development of better intuition. Personalized services for the students should be created. The problems are linked to the size of the realization of the program that challenges the authors with all the problems of innovation and of the different models of teaching presently being debated.

The Guides : the modalities of use should be thought about and explanations should be developed by the teachers. How to give the students help adapted to their various learning strategies ? How to reconcile guides and develop the students'autonomy ?

Adaptation of the resources : the possibility for a teacher to make a partial use of resources, to modify them and to integrate them into his own courses is an essential point. The *On-Line University* modules will be completely effective if they are used as a tool by teachers and if they give to students precise work to do using them.

Small grains : two ways of creation of grains to be used by the teachers to create their own teaching material with *On Line University* will be provided inside the R.U.C.A.
— one is to share the units in small independant and self contained grains, without any external link. The teacher will use these grains inside his own creation of resources.
— the other is to provide an hypertexte structure that allow partial integration of units and several ways of use adapted for different kind of students.
The future will be the use of XML for indexation of all the produces. A following up of metadatas for educational purposes is done by members of the R.U.C.A. but convenient tools are not yet at the disposal of the authors.

E-learning platforms : the integration of resources to combine presential work with the teachers and remote access to resources for personal work is a new problem in France. Each University of the R.U.C.A. choices its e-learning platform and this software in itself is not suffisant. Researches in educational sciences show that there is a risk that these tools create more isolation for the students. How to create collaboration between students for learning ?

2 Technologies in Mathematics

I shall deteal the problems that i have encountered as author of *On Line University* and of a book [8]. I fell that producing multimedia resources is different than writing books. One can see that many resources on the Web are just paper material put on line as *pdf* or *html* files.

2.1 Mathematics writing

Exploiting the possibilities of multimedia is not a part of the current culture of the authors. Animations and visualizations bring deep changes in the creation of resources. The possibility of experiment in mathematics is still in its initial phase. Significant progress can be seen with the use of *Java applets* in the unit *Differential Equations*[9].

2.2 Creation of teaching material in Lille

For many years, we have produced and share pedagogical material inside the mathematics department of the U.S.T.L. We have an exercice data base, printed courses and experimental software using *dos*, each of two hours teaching :
— linear algebra and Gauss pivoting method for linear system;
— visualization of integration methods;
— qualitative study of differential equations;
— ε, δ definition of convergence of a sequence.
Last year, new versions of these software have been developped using *java applet*. One can be seen in the exercice part of the *Integration* module of *On Line University*.

The first module of *On Line University* created in Lille is a transition program between secundary school and university, including *Logics and Naïve Set Theory*, *Elementary Arithmetics* and *Geometric Introduction to Linear Algebra*. The main objective was to provide to students many exercices from elementary ones to more conceptual ones, with immediate self-assessment. This was done using *javascript* and *many multiple choice questions*. Writing answers models are also analysed. Each exercice has a link with a lesson and a return button prevents disorientation inside the hypertext. A printed *pdf* version of the course material is also avealable inside the centers of multimedia resources. The unit about Taylor series and *Limited Developments* of functions [10] relies on the same objectives. We have used many graphs created with Maple and integrated in ordinary *html* pages, a limited attempt to exploit the possibilities of formal computation. A beautiful *java applet* for experimental work is provided inside this unit.

2.3 Mathematical typography

The whole set of mathematical symbols is not yet implemented in the browsers. Generally the teams of the R.U.C.A. do not use *LaTex* nor *Tex*; the choice of creating pictures for mathematical symbols was natural and the researches about mathematical typography are ignored by the staff of the program. In Lille, there are specialists of

[8] La fabuleuse histoire des nombres, Diderot édition, 1998
[9] by V. Gautheron (Paris 7) and E. Isemberg (Paris 11)
[10] a separate chapter in French books, but not in English ones

mathematical typography. There, our resources were in *LaTex* and we knew the state of art about the use of *LaTex* for the WEB [11]. While waiting for the implementation of *mathML* in the browsers, several attempts were done to use *LaTex* and *pdf* and rejected by the staff of the program[12]. With the software package *LaTex-for-html* [13] *gifs* were created for every mathematical symbol, four size *gifs* for each. The same *gif* is used in all the files and the next change, when *mathML* is available in all the browsers will be easy. *MathML* will solve the problem of composition of symbols in the formulas.

2.4 Multimedia material using *LaTex*

All the possibilities of *LaTex* are not always exploited by the mathematicians. With *LaTex*, you can create slides, conference material, insert pictures, graphs and hyperlinks. The conversion to *pdf* files is easy. For my work in history, i make a systematic use of *LaTex*. I teach the *History of Mathematics* both to students and to teachers. Some of my papers and teaching material [14] are on the WEB on the site of the LAMIA laboratory [15], in the I.U.F.M. [16]. For *The History of Pythagoras Theorem*, i have done many *java applets* using *cabri* [17]. I have a *pdf* a printable file but on line, you can click on the pictures open a pop-up window with an applet and use the hyperlinks. A *html* version was created with *LaTex-for-html*. I train my students and the trainees to use the Internet resources by providing in my teaching material hyperlinks to many websites and i show them how to analyse and make a critical use of such material. So, the mathematicians have many possibilities to use their professional word processor *LaTex* to create easily multimedia resources.

3 Integration of Technology

3.1 Important Efforts

These last few years, a very large financial support, often in association with European funds was made to equip universities, primary schools and secondary establishments. Altogether, the equipment of the establishments has grown very fast. Many colloquiums are organized at several levels for management staff and teachers. A national portal for the visibility of educational resources on the Internet has just been created for primary and secondary school teaching [18] and another one for academic teaching [19].

At U.S.T.L., seven centers of resources are equiped with about two hundreds computers and the animation is done by the S.E.M.M. [20] Fourteen young people are employed for supervision of these centers during opening hours. Now, the main use of

[11] see: The *LaTex* Web Companion, Integrating *Tex*, *HTML*, and *XML*, Michel Goossens and Sebastien Rahtz, Addison Wesley, (1999)

[12] see Cousquer paper

[13] on the C.T.A.N, Comprehensive *Tex* Archiv Network

[14] http://www.lille.iufm.fr/labo/cream/Histoire/cadreEntreeHistoire.html

[15] http://www.lille.iufm.fr/labo/laboProjetsReal.html

[16] A training college where i am head of the multimedia laboratory LAMIA

[17] a dynamic geometry software with possible conversion to *java applets*

[18] http://www.educanet.education.fr

[19] http://www.educasup.education.fr

[20] http://www-lemm.univ-lille1.fr/; Service d'Enseignement Médiatisé et Multimédia

these computers is the mail, chat and forum on the WEB. Interesting use for personal researches and use of pedagogical multimedia exist but are not principal. The students are very fond of these centers of resources that are full all day long. This in turn questions the teachers who see this interest of the students. How to avoid the situation met some years ago, where many establishments were equipped with computers which were used only by some colleagues keen on computer science among the general indifference of the other colleagues ?

3.2 Developments in Cognitive Psychology

The lack of previous products is explained partially by the state of research in cognitive psychology and by software package performance. At the early stage of its development, computer-assisted training was linked with behaviour theories and led to many pieces of software being produced where students were strictly guided on a path of questions and answers. This aspect quickly found its limitations in view of the difficulty for researchers to elaborate a *model of the pupil*. It had the same limits as the underlying conceptions of teaching. With the development of artificial intelligence, some expert systems were created and the training intelligently assisted with computer was developed, but resulting products remained marginal. The current state of computer software development with systems based on hypertexts and the use of Internet, introduces a qualitative change which makes a larger use of these tools in training possible. With the development of friendly user tools, the problems becomes different. Even if techniques are very important, didactical content becomes essential. The main objective is the integration of these technologies in teacher training and in the teaching of pupils.

3.3 Collaboration

Network based learning is now well developped, specially in U.S.A. and U.K. and it is possible to examine progress and draw conclusions. These three last years, i have animated a workshop in the I.U.F.M. about collaborative learning. We have studied many experiences [21]. A good synthesis can be found in the paper of Anderson and Jackson and in the book of P. Dillenbourg. Several laboratories of the North of France cooperate in *Formascience* program based on these ideas [22]. We all share the point of view of Scott Grabinger about the necessity of R*EAL Rich Environments for Active Learning* and i have tried to apply the same ideas in my own teaching.

3.4 Experience in the math department of the U.S.T.L.

We have done progress in the integration of multimedia. The department have decided an experimentation in 2001-2002. A CD-rom of resources avealable for the first academic year have been created, gathering units of *On Line University* and other resources; it has been distributed to 800 students of the first academic year [23]. Each group has

[21] cf the ieee journal of 2000 July

[22] piloted by Alain Derycke and Chantal d'Halluin (U.S.T.L.)

[23] 27 groups : 15 deug Mias, (Mathematics and Computer Science), 8 deug SM, (Physics and Chemistry), 4 deug Mass, (Mathematics and Economy)

received from his mathematics teacher a CD-rom and organized the diffusion. So the resources act as help for personal work. Several teachers use the practical software in center of resources, new teachers are engaged in creation. A network of mathematicians animate a workshop of formal computation and its use in teaching.

In 2000-2001, i have tried two uses of an e-learning platform inside my teaching, in a center of resources. The first experience was not convincing and i understood that, without new teaching methods, these tools are not interesting for presential students. So i prepare a new experiment in *History of mathematics*. This experience was very positive. First, i do not explain the functionalities of *Campus virtuel*. The students dicovered them progressively with new tasks to fullfil. The forum was used by teams of students to solve open problem given without answers. They have to find collectively the answers; each team had the responsability of one subject and the task to organize a structured discussion to find the solutions. The students were very motivated and some discussions were very interesting and rich.

4 Conclusion

Mathematics has very closed links to computer science both for fundamental research, (logic, algorithms, codes, geometry, formal computation) and for applications. This link increases now and the new technologic tools are going to change deeply the teaching of mathematics, with the possibility of simulation, visualization and experimentation. A French committee is prospecting the future trends of mathematic teaching from primary school to university [24]. A strong idea is to develop laboratories of mathematics in secundary schools. The Mathematics department of the U.S.T.L. is engaged in a reflexion about teacher training : the new technologic tools rely upon mathematics and mathematic teachers can have a determinant role to impulse use of technologies by pluridisciplinary teams of teachers. So the question is : how to impulse a high level training both in mathematics and in the use of technologies ?

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[24] http://smf.emath.fr/Enseignements/index.html, Commission Kahane